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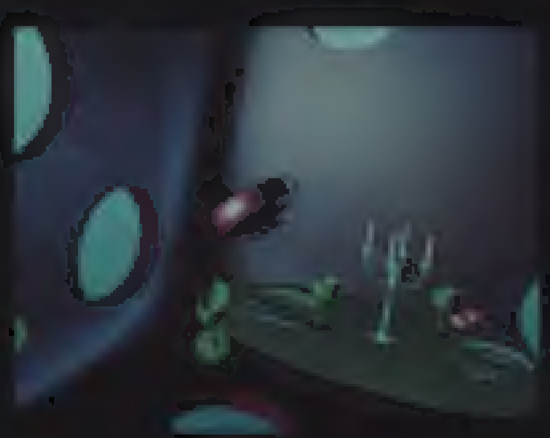

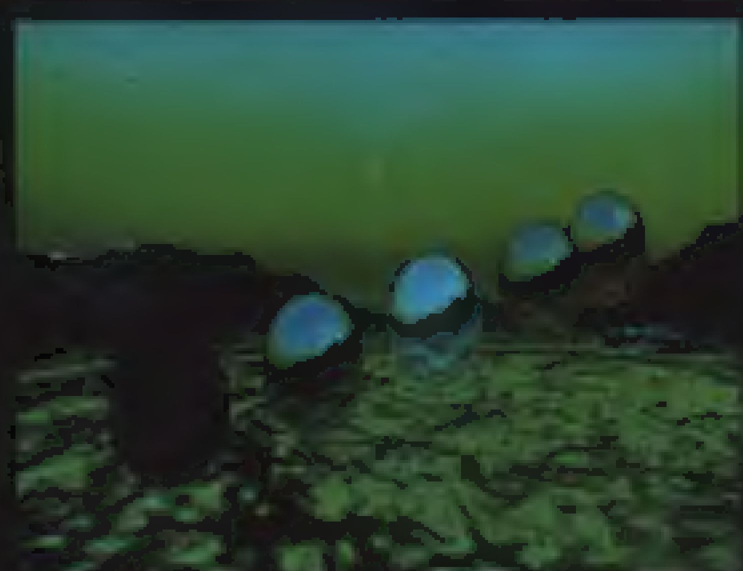

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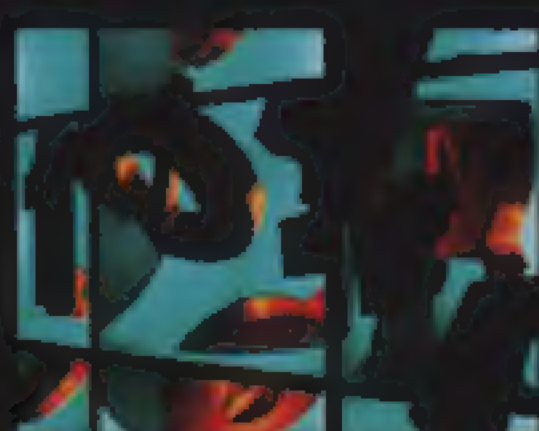

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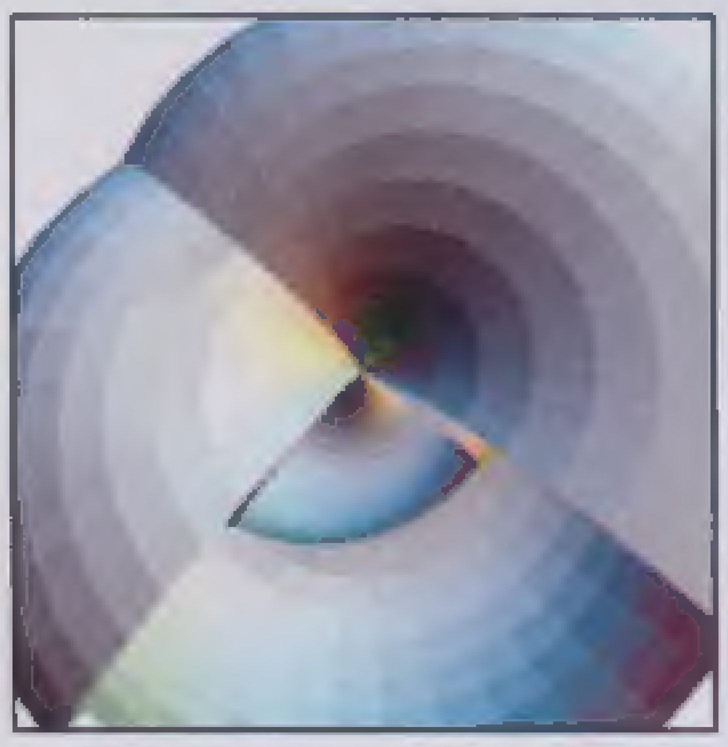

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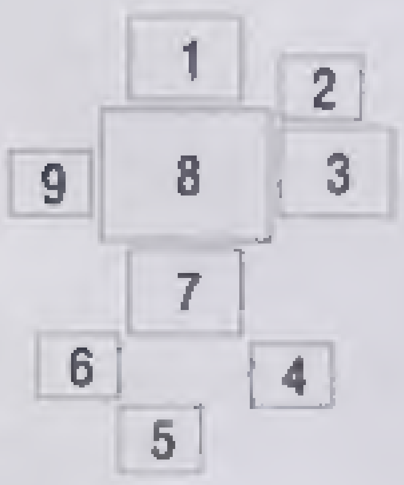
FEATURES

DEPARTMENTS



ON THE COVER
A selection of images from colleges and universities throughout the country created on Silicon Graphics systems. 1. A visualization of the components of smog in the Los Angeles basin, Matthew Arrott, Mark Bajuk, Aliza Corson, Michael McNeill, William Sherman, University of Illinois at Urbana-Champaign, National Center for Supercomputing Applications. 2. Jennifer Steinkamp, Art Center College of Design. 3. Rajesh Naiksatam, School of Visual Arts. 4. Jane Veeder, San Francisco State University, Advanced Computer Imaging Center. 5. Ronald Impas, Art Center College of Design. 6. Chromium chloride density difference contours from a visualization of catalysis research, Jeffrey Thingvold, University of Illinois at Urbana-Champaign, National Center for Supercomputing Applications. 7. Jackson Chan, Art Center College of Design. 8. Reflection Study No. 6, © 1986, Vibeke Sorensen, produced at CalArts CAL, California Institute of the Arts. 9. Stig-Harder Andreassen, Art Center College of Design.

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THE MAGAZINE OF VISUAL PROCESSING

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(Solutions)

Design Francesca Angelesco

Digital Images Monica Schulze and Paul Haeberli

Typesetting Lauren Langford Typography

Color Separations American Color

Printing Pendell Printing, Inc.

Editorial Silicon Graphics, Inc.
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Mountain View, CA
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IRIS Universe: The Magazine of Visual Processing, is published quarterly by Silicon Graphics, Inc., and is dedicated exclusively to the needs and interests of the Visual Processing community. Please send address changes to "IRIS Universe, Silicon Graphics, 2011 North Shoreline Boulevard, Mail Stop 415, Mountain View, CA. 94039-7311." Subscriptions are available upon request to qualified users. Others may subscribe at the following rates: $14 per year (USA), $16 per year (Canada), $26US per year (Overseas). Please make checks payable to Silicon Graphics, Inc.Fill out the postage-paid subscription card in this issue or call (415) 962-3320. Correspondence regarding editorial (press releases and product announcements) should be sent to "Editor, IRIS Universe, 2011 North Shoreline Boulevard, Mail Stop 415, Mountain View, CA 94039-7311". Phone: (415) 335-1727. Letters to the *IRIS Universe* or its editors become the property of the magazine and are assumed to be intended for publication, and may be so used. Correspondence should include the writer's full name, address, and telephone number. All letters may be edited for clarity and/or space.

EDITOR'S NOTE

EDUCATION AND VISUALIZATION

It's no surprise that as visual processing computers become increasingly ubiquitous in art, design, and the sciences, their use in colleges and universities is also becoming more prevalent. Whether applied to industrial design, animation, archeology, or any number of disciplines, visual processing workstations are now bringing the same advances to education that industry has enjoyed for much of the last decade. This issue's cover article looks at just a handful of the many academic institutions which use IRIS workstations as a teaching and learning tool.

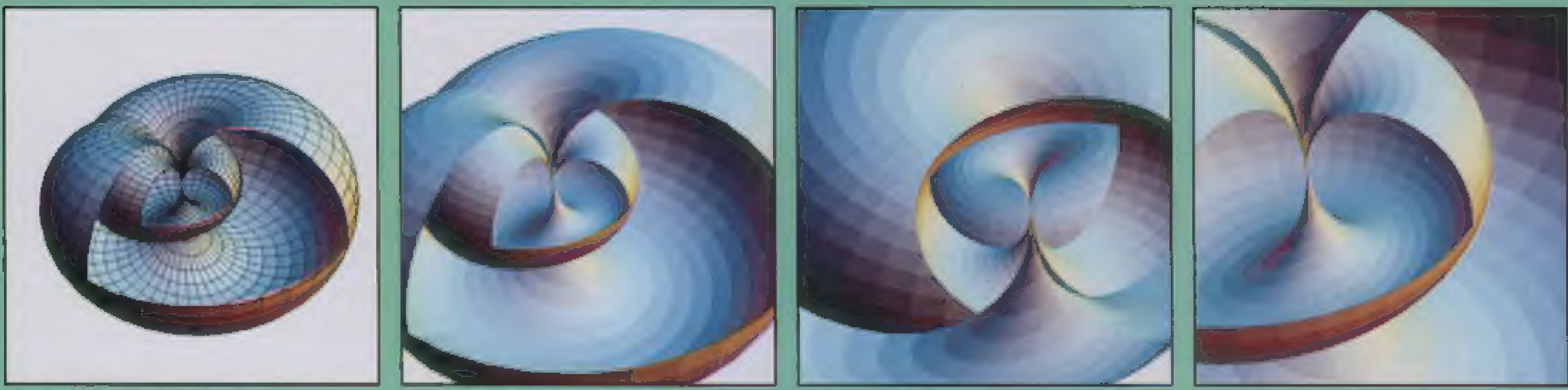
At the University of Illinois' Renaissance Experimental Laboratory, interdisciplinary teams of scientists and artists are working together on the visualization of scientific information. In Pasadena, California at Art Center College of Design, the next generation of industrial designers are using 3D computer graphics to learn transportation design. And at Princeton, IRIS systems are used to create interactive models of archeological sites. At these schools and numerous others the interactive, intuitive power of computer visualization is permanently changing the way people learn, work, and collaborate.

As Dr. Timothy Binkley, Chairman of the Computer Art Program at New York's School of Visual Arts commented recently, "Our students, with either artistic or technical backgrounds, learn...using an intelligent machine which functions more as an active creative partner than a passive medium."

Clearly, with the continuing increase of visual processing workstations in the academic environment, research and learning promise to take on extraordinary new dimensions.

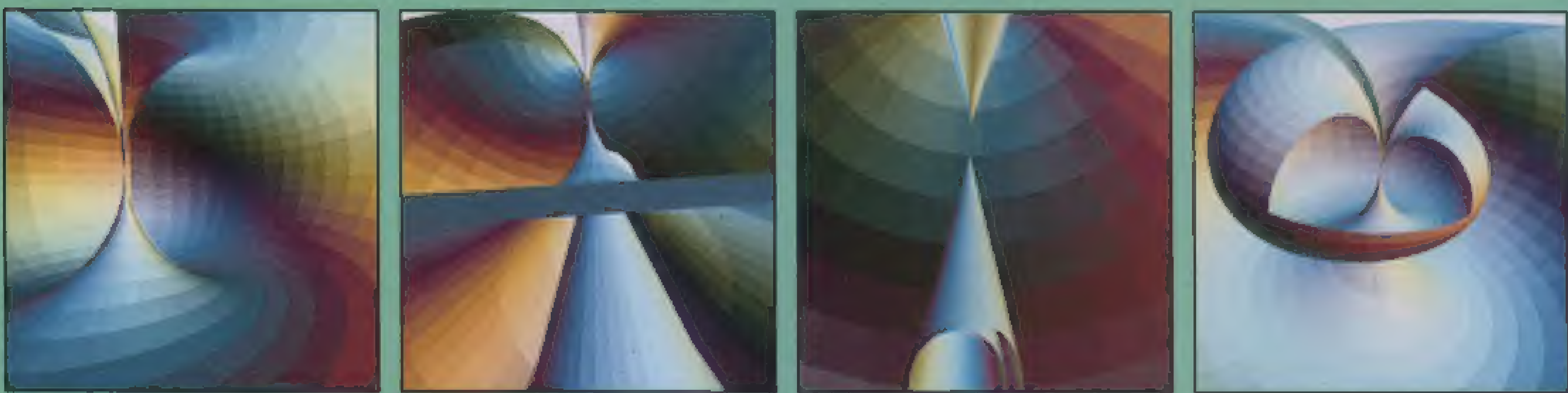
— *Douglas Cruickshank, Editor*

BY PRASHANT PAREKH



Mathematica™ is an interactive software system that incorporates a high-level programming language and performs numerical, symbolic, and graphical computations. Mathematica can plot functions and data in 2D and 3D, in black-and-white or color, allowing the user to visualize results of calculations. Mathematica can also take symbolic descriptions of arbitrary geometrical objects and translate them into three-dimensional color pictures.

The symbolic and graphical computational capabilities of Mathematica software were used in the generation of the object in this sequence of images. The ability to visualize this type of complex function, and to view the resulting graphical object from different perspectives, is an important and valuable one. Mathematica's "LIVE" feature on the Silicon

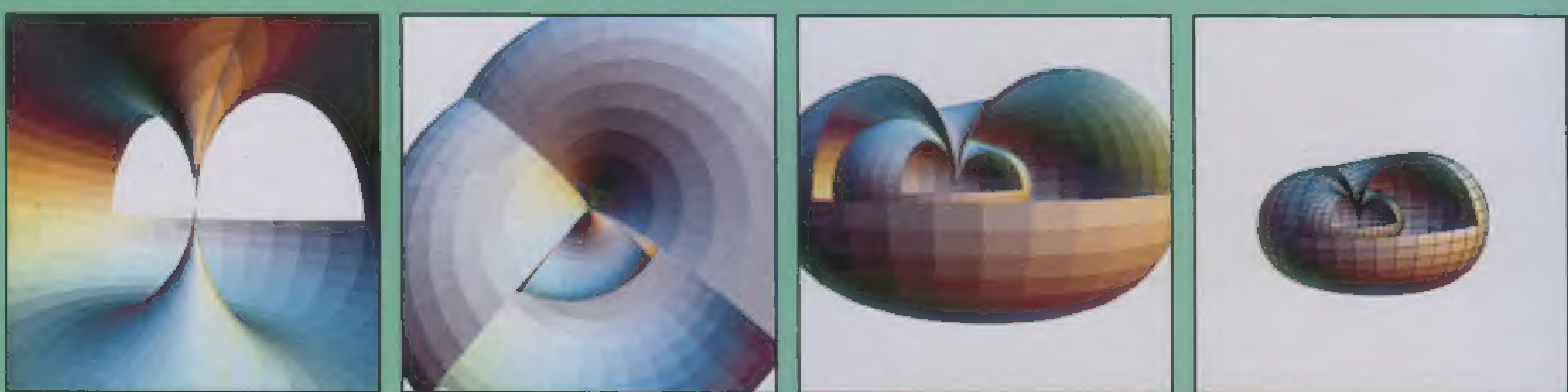


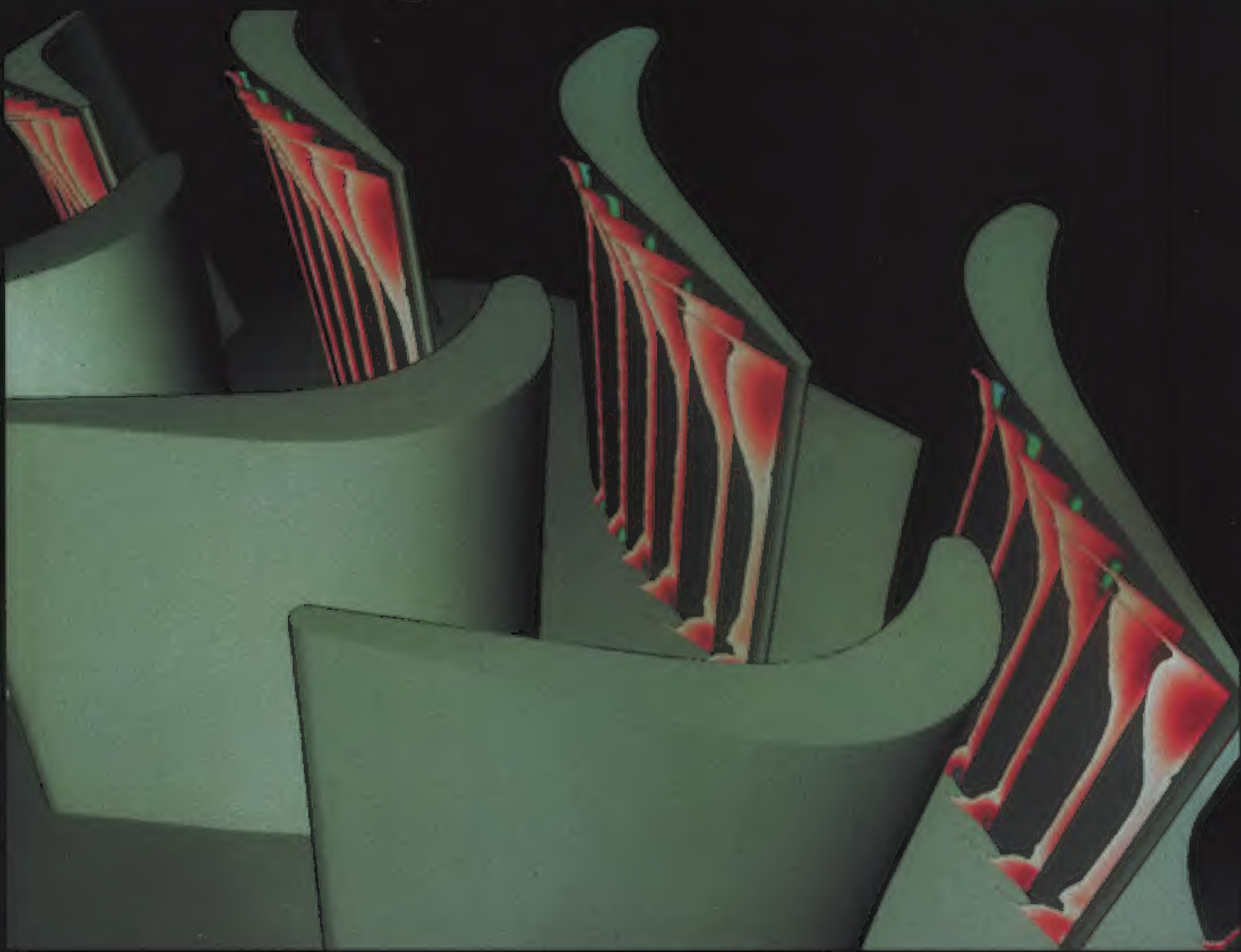
Graphics hardware allows the user to control the viewpoint and other parameters in real-time. This feature is used to move about or fly through the object.

In this sequence we fly through a graphical object which represents a mathematical function defined as a variant of a spherical plot of sin theta. This function gives us a doughnut shape in which the central hole shrinks to a single point.

The equation for this function is: Sin[theta] * (radius) where {PI/2 < theta < Pi} and the radius is defined by the function 2 + cos phi/2, {0 < Phi < 4Pi}, giving us a radius that lies between 1 and 3, and closes up after two revolutions.

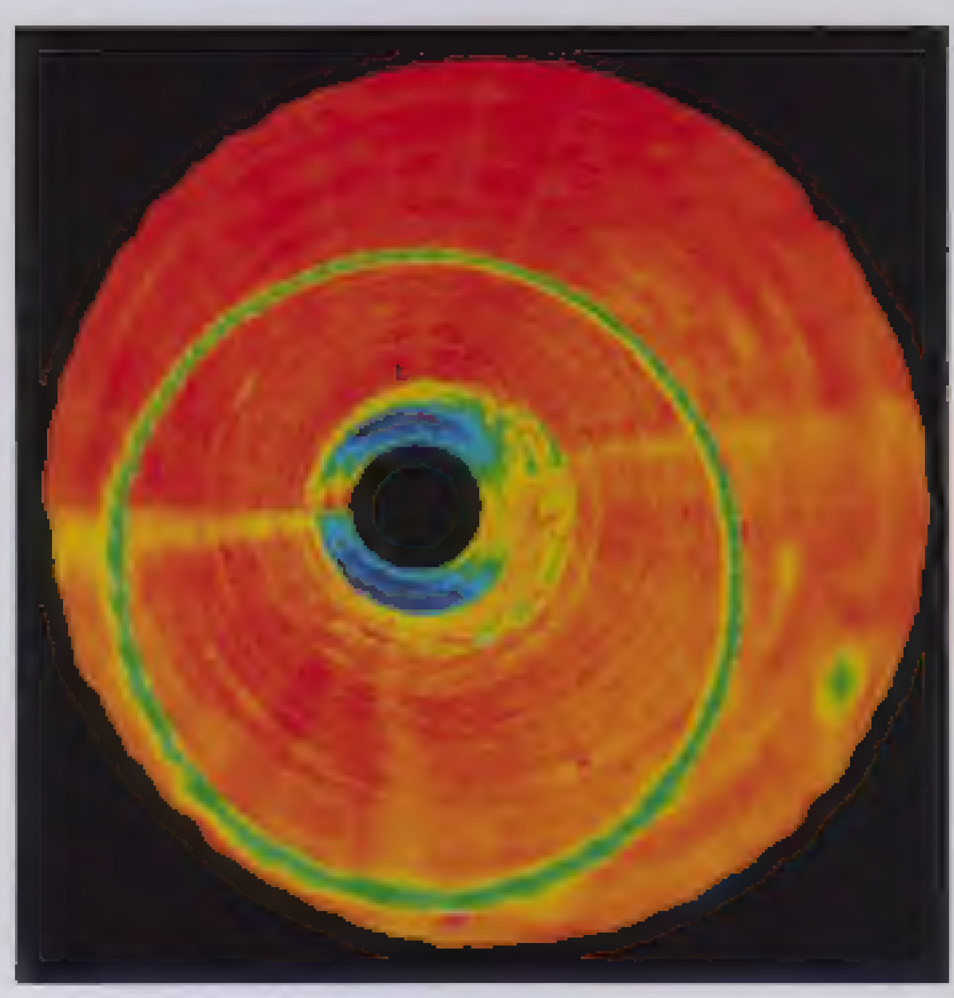
Prashant Parekh is a Product Marketing Manager at Silicon Graphics.

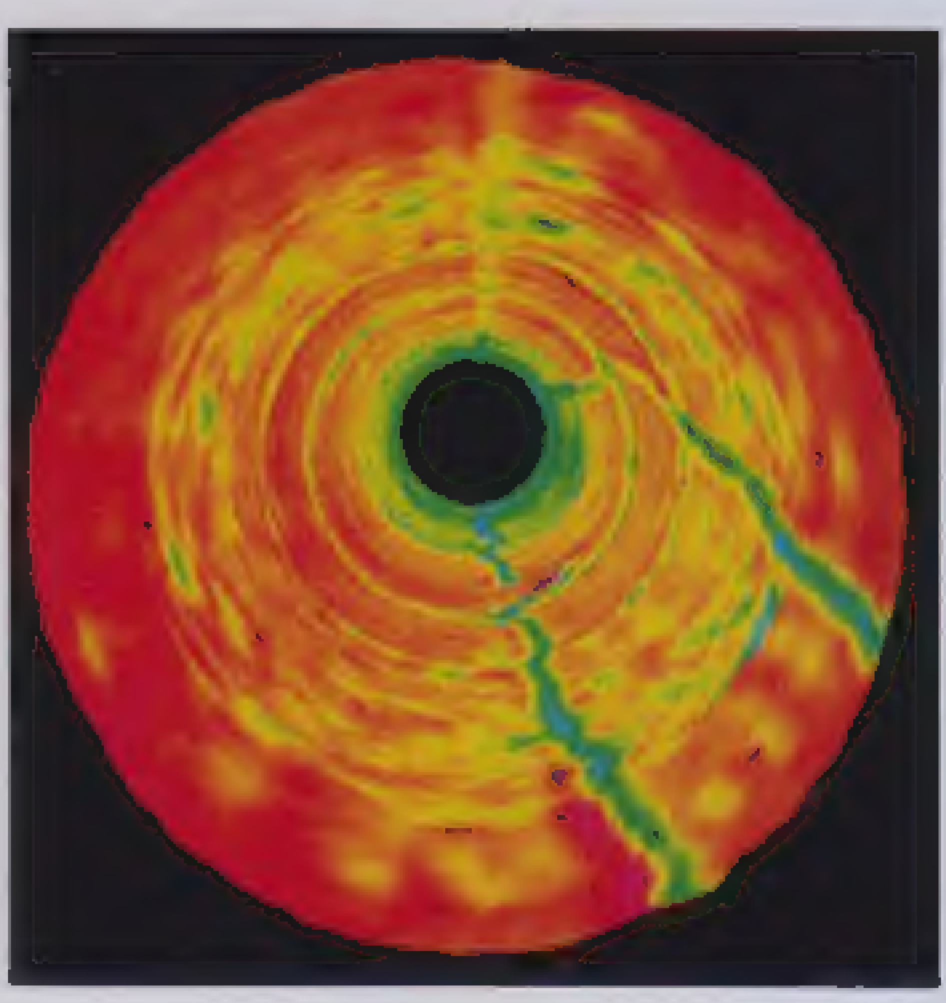




TRANSPARENCY IN A GEOSCIENCE APPLICATION: *Visualizing Fractures In Boreholes*

BY
JEAN-PIERRE PANZIERA
and ROBERT PETTE





The BoreHole TeleViewer (BHTV) is a logging tool used by structural geologists and reservoir engineers to determine the geometry of a well and the nature of borehole materials. The Televiewer fires acoustic beams down the well and records the sound reflection time and amplitude. High definition of the data enables the engineer to detect thin fractures in the well bore.

The traditional visualization of borehole data is a two dimensional display with azimuth plotted horizontally, and depth vertically. On amplitude display a vertical fracture appears on these plots as two vertical lines. Its direction cannot be directly determined. An oblique fracture will show as a sine curve, its orientation is difficult to compute.

On the IRIS, three dimensional display gives one a direct understanding of the borehole characteristics. One view can summarize the geometry and the elastic rock properties of the borehole. The viewer can move around the well, look at it from the inside, and see things as they appear underground without being there.

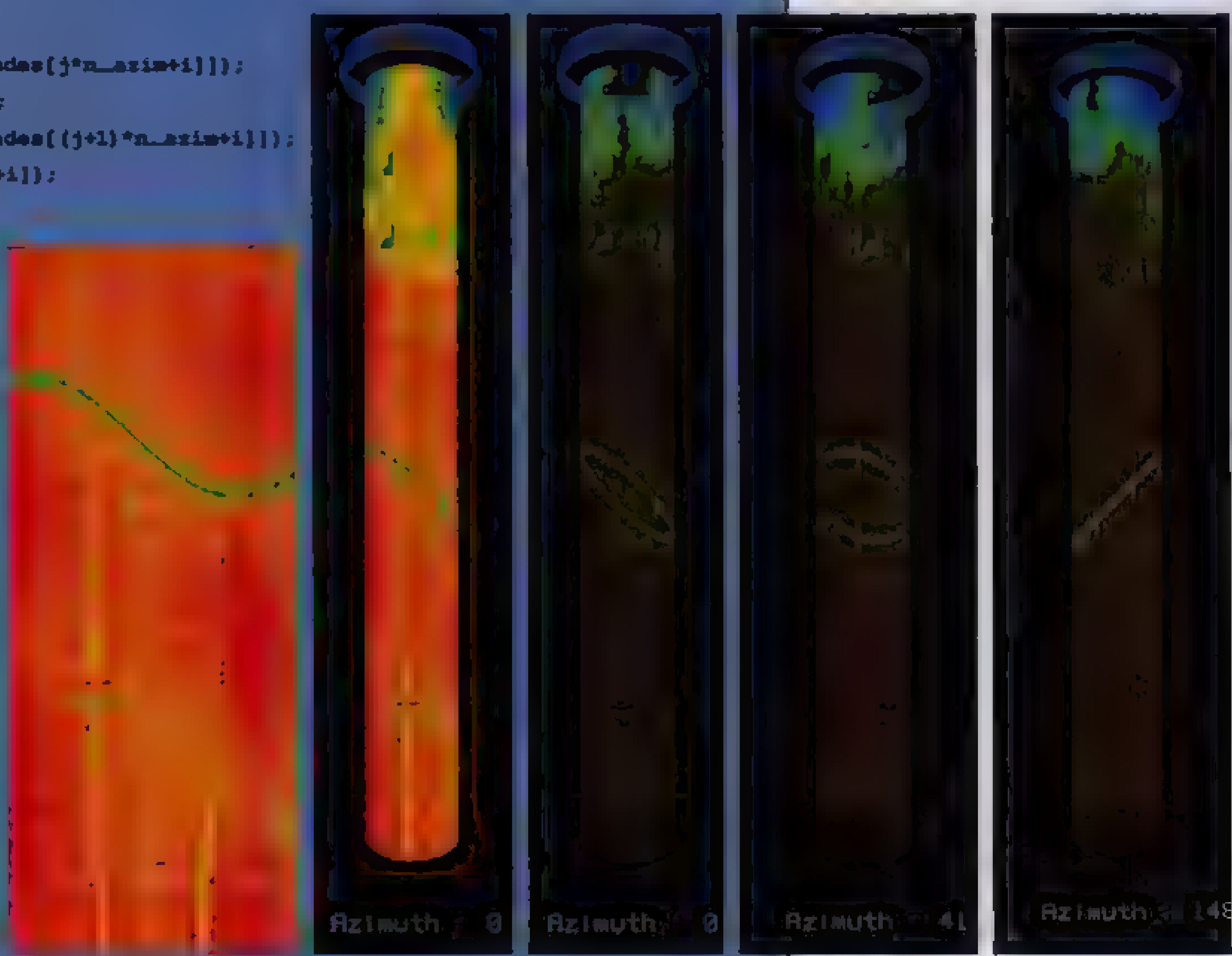
With transparency, fracture orientation can be intuitively understood. To isolate the fractures, we display only the lower amplitude reflections (cooler colors). Then if we move around the well until the two sides of a fracture are aligned, the azimuth bearing gives a direct reading of the fracture direction. This is basically the same method structural geologists use in the field.

Transparency implementation is achieved by testing each individual value at display time, and plotting only the values above a set threshold. Unfortunately, this method is CPU intensive.

A faster implementation uses the alpha-bitplanes available on the IRIS GT & GTX machines. This approach, illustrated by the program fragment accompanying this article, leads to a simple code that enables the use of the high speed "tmesh" graphic routines.

Jean-Pierre Panziera and Robert Pette are Systems Engineers at Silicon Graphics. Panziera works in the Applications group and Pette in SGI's Houston office. Data courtesy of Halliburton Logging Services, Inc.

```
/* setting up the transparent-color table ( has 256 entries ) */
void setup_transp_table( max, transp)
  int max, transp;
{
/* color_table is the original ''cpack'' color table */
/* trans_table is the new transparent ''cpack'' color table */

  for ( i = 0 ; i < max ; i ++) /* low values are opaque */
      trans_table[i] = color_table[i];

  for ( i = max ; i < 256 ; i ++) /* high values are transparent */
      trans_table[i] = color_table[i] & ( 0xffffff | (transp << 24) );
}

/* displaying the semi-transparent borehole data */

void display_trans_data()
{
  blendfunction(BF_MSA, BF_SA);
  zbuffer(FALSE);

  for ( j = 1; j < n_depth ; j++)
    bgntmesh();
    for( i = 0, count = 0; i < n_azim ; i++, count ++ ) {
      if( count == 128) {
        count = 0;
        endtmesh();
        bgntmesh();
      }
        cpack( trans_table[amplitudes[j*n_azim+i]]);
        v3f( positions[j*n_azim+i]);
        cpack( trans_table[amplitudes[(j+1)*n_azim+i]]);
        v3f( positions[(j+1)*n_azim+i]);
    }
      endtmesh();
  }
  blendfunction(BF_ONE, BF_ZERO);
  zbuffer(TRUE);
}
```



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IRIS GOES TO SCHOOL

BY GAYE GRAVES

In which we look in on a few of the many colleges and universities now using IRIS workstations as an integral part of their curriculum, and find that innovation is alive and well.

1. Video Wind Chimes/Street Lights, Sheldon Brown, San Francisco State University 2. Reflection Study No 4, ©1986 Vibeke Sorensen, produced at CalArts CAL, California Institute of the Arts 3. Venus and Milo, Donna Cox, Christopher Landreth, and members of the Visualization Experimental Laboratory, University of Illinois at Urbana-Champaign. 4. Irene Chan, Art Center College of Design. 5. Habib Zargarpour, Art Center College of Design. 6 & 7 Michael Henne, University of California at Santa Cruz 8. Art Center College of Design. 9. Eugene Jeong, Art Center College of Design. 10. Using an IRIS Workstation at Art Center College of Design 11 Foothill Community College, Los Altos, California. 12. Estudo 2, ©1990 Eymard Porto, produced at CalArts CAL, California Institute of the Arts. 13. Wiliam A.P Childs, Princeton University. 14 Tsun-Chih Lo, School of Visual Arts.

Over the last few years, Silicon Graphics' workstations have become increasingly important in college and university programs. Whether studying art, design, or the sciences, students tend to be some of the most forward thinking users.

Recently Edward R. McCracken, Silicon Graphics' President and Chief Executive Officer, commented, "I think that industry should be deeply committed to university programs. We learn so much from the interaction with students. The vitality, energy, and enthusiasm that characterize universities is infectious, and of course so many new ideas come out of the collegiate community.

"It's exciting when a university is able to outfit an entire laboratory with our systems and design their curriculum around that facility. As students get more deeply involved, the positive impact of visual processing on research and learning becomes readily apparent."

The University of Illinois

The University of Illinois at Urbana-Champaign is experiencing a renaissance through computer graphics. The school is bringing together sciences and the arts through interdisciplinary teams in its Renaissance Experimental Laboratory (REL). Director of the REL, Donna Cox points out that, "Historically, it was during the Renaissance that we saw new disciplines emerging through the collaboration of artists and scientists working together to create biological/anatomical illustrations for books. At the REL," Cox continues, "artists and scientists come together to work on scientific visualization projects; the graphic visualization of scientific information".

Cox has used her artistic background to collaborate with scientists concerning the use of color in scientific visualization. She found that computer graphics provided the common language through which people of different disciplines were able to understand each other. Boundaries and roles began to blur when artists and scientists worked together. "As an educator," says Cox, "I want to see this process of collaboration handed down to students as a methodology of working."

The "Venus and Milo" animation shown in the Animation Screening Room at SIGGRAPH '90 was the first test of this methodology at the REL. It was created by members of the *Visualization Experimental Technologies* class, a collaborative interdisciplinary workshop in computer animation. The art and design students spent the semester learning how to design and animate using IRIS workstations and Wavefront software. Computer science students contributed their skills by bringing in data to the Wavefront software. "We didn't start running animations until the end of February this year," Cox says. "It's phenomenal that by May we had something ready to submit to SIGGRAPH."

The Renaissance Experimental Laboratory occupies one floor in the Beckman Institute. The classroom houses twenty Personal IRIS workstations. During semester breaks the REL classroom hosts seminars for teaching professionals about scientific visualization and the use of supercomputers.

Art Center College of Design

At Art Center College of Design in Pasadena, California, IRIS workstations are being put to a different use. Art Center has trained more than half of the leading transportation designers in the United States, Japan, and Western Europe. It's likely that the car you're driving today was designed by an Art Center alumni. Two members of the three man team that designed the Mazda Miata graduated from the college.

Ronald Hill, Chairman of the Industrial Design Department was formerly a chief designer at General Motor's Advanced Aerodynamics Studio, where he was involved with the incorporation of computers into GM's design process. Hill has been a principal force behind Art Center's purchase of IRIS workstations and Alias software. "It is crucial for today's students to have a 2D computer background," Hill says, "3D is a luxury now, but in three to five years it will be essential. Although hand rendering and clay modeling skills are still necessary, 3D computer graphics has advantages. Hand rendering may sometimes obscure a design flaw, but 3D doesn't lie!"

The *3D Computer Modeling* class focuses on aspects of 3D model building for design, photo-realistic rendering, and image composition. The system enables students to visualize their designs in true 3D form as well as place them in a 3D environment. "We have found", says Systems Administrator and animation instructor Jennifer Steinkamp, "that Alias gives us the flexibility we need to create complex curves," such as those shown in the model of an automotive engine built by student Irene Chan. The physical model was built as part of a team project. Chan rebuilt the engine in order to learn how to create models on the IRIS.

Under the guidance of Hugh Dubberly, Chairman of the Computer Graphics Department, Art Center hopes to integrate computer graphics into appropriate classes in *all* of its departments. Currently, Art Center's academic departments include: Advertising, Computer Graphics, Graphic and Packaging Design, Film, Fine Art, Illustration, Industrial Design, and Photography.

Leon Cannon,
Foothill Community College,
Los Altos, California.

California Institute of the Arts

California Institute of the Arts (CalArts), located forty miles north of Los Angeles, is the alma mater of numerous computer graphics and animation luminaries; among them, Pixar's Academy Award winning character animator John Lasseter ('79). CalArts was established through funding from Walt Disney and the Disney family. The Institute was created by merging the Los Angeles Conservatory of Music with Chouinard Art Institute.

According to CalArts' President Steven D. Levine, "The founders imagined a community of artists where those of great accomplishment would foster the growth of gifted students... It was a remarkable dream and, as I view CalArts today, that dream has, to a large extent, come true."

In 1984, with a grant from the Jones Foundation, CalArts School of Film and Video established the Computer Animation Laboratory to provide computer graphics for students from all disciplines. Vibeke Sorensen, Director of the Lab,

believes that "It was important to match the quality of the technology with the quality of the imagination of the artists."

The Lab houses three 3000 series IRIS workstations running Wavefront software and four IBM PCs or compatibles running either Cubicomp's PictureMaker or ModelMaker. Recording devices include: two Lyon-Lamb VAS-IV's, two Sony 5850 video recorders, and a 16mm Mitchell camera.

Courses such as the advanced computer animation course taught by Assistant Director of the Computer Graphics Lab, Juan Cordova, span two semesters and are limited to four students. The first semester is spent learning computer animation techniques. Each student creates an independent project during the second semester. Students with little computer background start with the courses which use Cubicomp software and IBM compatibles. The IBM machines and the IRIS workstations are networked to facilitate file transfer.

Eymard Porto, a native of Brazil, is an MFA student in experimental animation. He is working on an animation which will composite live action rotoscoped images into a computer generated turn-of-the-century street scene in Rio de Janeiro. The buildings are 3-D models which can be rotated and moved through. The floors and some of the textures were originally built by Proto using Cubicomp.

Instructors at CalArts are encouraged to produce personal art while teaching at the school. Juan Cordova is working on an animation project in which he is exploring methods for using Wavefront software to create the effect of fire without employing particle systems.

Vibeke Sorensen, meanwhile, is working on a project called "Reflection Study Series," which consists of several stereo pieces and deals with the role of scale and visual perception. Referring to the gold-hued image (number 2 on page 12), Sorensen explains, "This is a strange sculpture placed inside of a cylindrical tube. The sculpture inside the cylinder has irregular contours on its surface. When it reflects the environment map on the cylinder, the map is warped by the original shape."

Princeton University

Princeton University has approximately ninety IRIS workstations, twenty-five in the Interactive Computer Graphics Lab (ICGL), part of the Department of Computing Information and Technology (CIT). A variety of technical, non-academic courses are taught in the Lab's two classrooms. The ICGL emphasizes the support of individual research projects.

One such project is that of William A. P. Childs, a professor in the Department of Art and Archaeology. During his archeological expedition to Polis, Cyprus, Professor Childs used IRIS workstations and ICGL visualization tools to illustrate the ancient city site (1.5 x 1.5 km) and individual excavations within that area. The visualizations depict detailed topographical features of the location.

At the site, using a laptop PC, each artifact's description and the location of its discovery was entered into the database. Then, as the site was marked with a surveyor's grid, coordinates of the artifact's location could be recorded. This information was used to create a 3D wireframe representation of the dig. Icons representing the artifacts appear on the grid where the antiquities were unearthed. Different icons represent different types of artifacts. The artifacts themselves were photographed and scanned in.

Once back at Princeton the data was transferred to an IRIS workstation, in order to create a 3D, *interactive* wireframe model of the site. Using the mouse, one can then move around the site, viewing it from different perspectives. If one clicks on an artifact icon, a window opens which is the interface to the database. In the window, pertinent information about the artifact is listed, such as its original location and condition. A scanned photograph can also be brought up in a window.

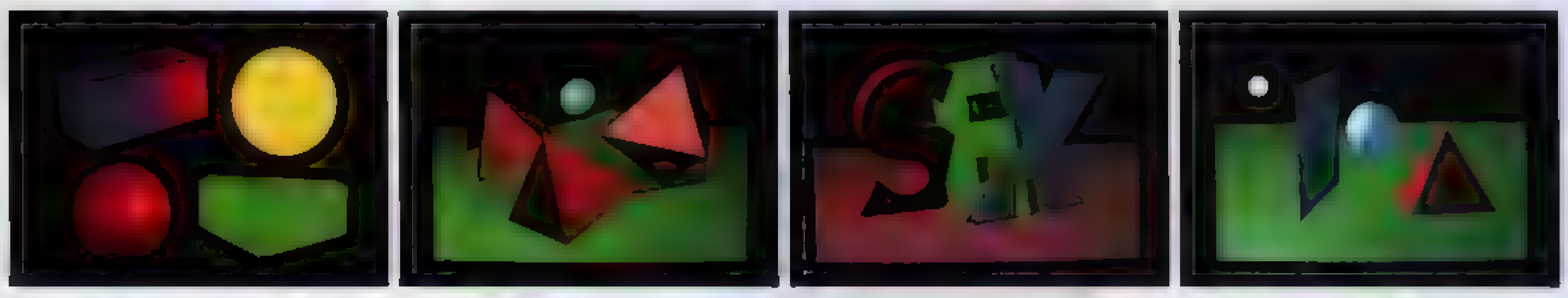
This interactive database gives the archaeologist a new way of seeing and understanding excavations.

The School of Visual Arts

New York's School of Visual Arts (SVA) draws it's MFA Computer Art students from a mix of designers and non-designers. Dr. Timothy Binkley, Chairman of the Computer Art Program, described the course of study as one in which "students with either artistic or technical backgrounds learn how to create art using an intelligent machine which functions more as an active creative partner than a passive medium. Computer art provides many opportunities for industrious individuals."

The IRIS workstations at SVA are usually reserved for the MFA Computer Art graduate students. The lab houses three Personal IRIS Workstations, one of which is dedicated to rendering.

The PIs are used primarily for 3D animation and modeling classes. The work of one SVA animation student, Tsun-Chih-Lo, "The Untouchable Diamond", was included in the SIGGRAPH '90 Animation Screening Room in Dallas.



Training images created by Jane Veeder, Director of San Francisco State's Advanced Computer Imaging Center. The purpose of the series is to acquaint students with how 3D *Reflection Objects; Object Interpenetration; Light with Shadows; Light (Without Shadows) Going Through Objects; Light Exclusion.*

Pratt Institute

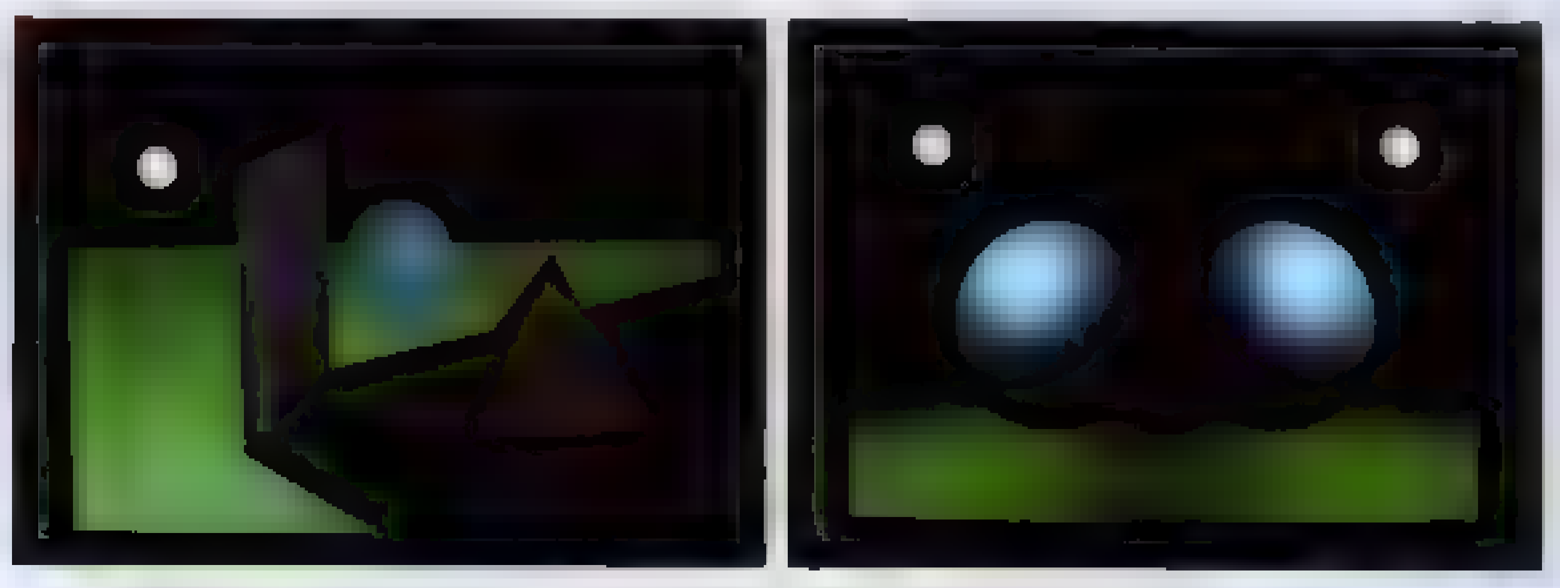
A short distance away, the Pratt Institute also offers a Master of Fine Arts degree in Computer Graphics. The designers of the curriculum at Pratt believe that proficiency in computer graphics best prepares students for today's changing workplace, an environment in which graphic design studios use micro and mini computers for performing tasks that just a few years ago were done by hand.

Pratt's six IRIS workstations, purchased in 1987, are reserved for 3-D modeling and animation courses. These courses are open to both the upper division Computer Graphics Bachelor of Fine Arts students as well as the MFAs. Isaac Victor Kerlow, Chair of the Computer Graphics Department recalls, "When I first came to Pratt in 1985, I developed the 3D modeling and animation courses on a VAX 11/780. I've rewritten those courses for teaching with the IRIS."

University of California at Santa Cruz

At UC Santa Cruz's Baskin Center there is a wide range of computing research taking place. The Computer Graphics and Image Processing research is found within the Computer and Information Sciences Department (CIS). Under the tutelage of CIS Assistant Professor Jane Wilhelms, known in her own right for work on graphically simulating the motion of humans and robots, is graduate student Mark Henne. Henne's interests lie in the area of physical simulation. Physical simulation refers to the generation of motion using dynamics equations from physics. Constraints can be applied to produce controlled motion and to take into account environmental interactions.

The flexing arm visualization (numbers 6 and 7 on page 12) was created by Henne for his Master's thesis "Dynamic Skin for Articulated Bodies." The goal of the project was to create a



animation software works. Left to right: *Color, Dissolve, Normal and Bevel;*

flexible skin model which deforms naturally over joints, accommodates muscle bulging, and provides for dynamic response to rigid body motion. This was accomplished by specifying the skin as a stretchable surface under the influence of localized vector fields. These vector fields represent the volume of tissue taken up by bone, muscle, fat, and organs. The interactive program for experimenting and motion preview ran on an IRIS 4D-50/G. The final images were produced with PhotoRealistic Renderman on the IRIS. Most of the dynamics computations were performed on an IBM RS/6000 model 320.

"I needed the IRIS," Henne says, "to do real-time visualization."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  - ☐ Pharmaceutical
  - ☐ Other Life Sciences
- ☐ **Computer Sftwre. Dev.**
- ☐ **Education**
- ☐ **Other**________

My application interests are:

- ☐ Animation
- ☐ Architectural Design
- ☐ Artificial Intelligence
- ☐ CAE
- ☐ Finite Element Analysis
- ☐ Fluid Dynamics
- ☐ Image Processing
- ☐ Industrial Design
- ☐ Man/Machine Interface
- ☐ Mechanical CAD/CAM
- ☐ Mission Planning
- ☐ Molecular Modeling
- ☐ Pre-press
- ☐ Visual Simulation
- ☐ Robotics
- ☐ Scientific Visualization
- ☐ Other (Specify)________

My IRIS workstation is a:

☐ Power Series ☐ 4D/G ☐ Personal IRIS
☐ 4D/GT ☐ 1000/2000/3000 ☐ ________

The number of IRIS workstations at my site is:

☐ 1–5 ☐ 11–20 ☐ More than 50
☐ 6–10 ☐ 21–50 ☐ None

Software Utilized:

☐ Public Domain Software *(please specify)*
☐ Custom Software
☐ Third-Party Software

My job function is:

☐ Corporate Mgt. ☐ Engineering Mgt. ☐ Research Staff
☐ Marketing ☐ Engineering Staff ☐ Other________
☐ Consulting ☐ Creative Staff

My organization's total sales volume or budget:

☐ Less than $100,000 ☐ $101,000–$1 Billion ☐ More than $1 Billion

Number of employees at my company:

☐ Under 250 ☐ 251–5000 ☐ 5000 or more

I purchase or influence the purchase of the following graphics and imaging products:

- ☐ PCs
- ☐ Workstations
- ☐ Supercomputers
- ☐ Networking products
- ☐ Boards/controllers/subsystems
- ☐ Monitors/Displays
- ☐ Scanning/image capture devices
- ☐ Plotters
- ☐ Storage or memory devices
- ☐ Color Printers
- ☐ Laser Printers
- ☐ Hardcopy supplies
- ☐ Presentation systems
- ☐ Tablets, digitizers, spaceballs or other input devices

Do you use or own an SGI workstation? ☐ **Yes** ☐ **No**
If so, what is the serial number?________

What can Silicon Graphics teach you?

Please send me information on the following courses:

Name:

Title:

Company:

Address:

Phone:

- ☐ Graphics Programming I
- ☐ Graphics Programming II
- ☐ PowerVision Graphics
- ☐ Parallel Programming
- ☐ Mastering IRIX
- ☐ System Administration
- ☐ Network Fundamentals
- ☐ Self-paced Personal IRIS Maintenance
- ☐ System Maintenance
- ☐ Multi-processor Maintenance

Comments or Questions:

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San Francisco State University

At the Advanced Computer Imaging Center, one of the facilities at San Francisco State University's School of Creative Arts, Jane Veeder, Director of the Center, has created online interactive visual training examples on a Personal IRIS for the 3D animation students. The examples teach the students about modeling, rendering, and lighting. Veeder, who left Wavefront Technologies to head the Center, is teaching students to understand how 3D animation software works, so that, ultimately, they'll be able to translate that knowledge to any similar software package.

One of Veeder's graduates, Sheldon Brown, now a teacher at the Kansas City Art Institute, uses Alias software. While taking Veeder's classes, Brown used the Personal IRIS, Wavefront software, and video recording equipment to model an animation of a prototype for a proposed video-sculpture installation. The *Video Wind-Chime/Street-Light* (number 1 on page 12) is an outdoor illumination system which retunes the image it projects according to the movement of electromagnetic waves and the wind.

Learning and the Future

There is no question that the IRIS is becoming an important tool for both teachers and students at universities and colleges everywhere.

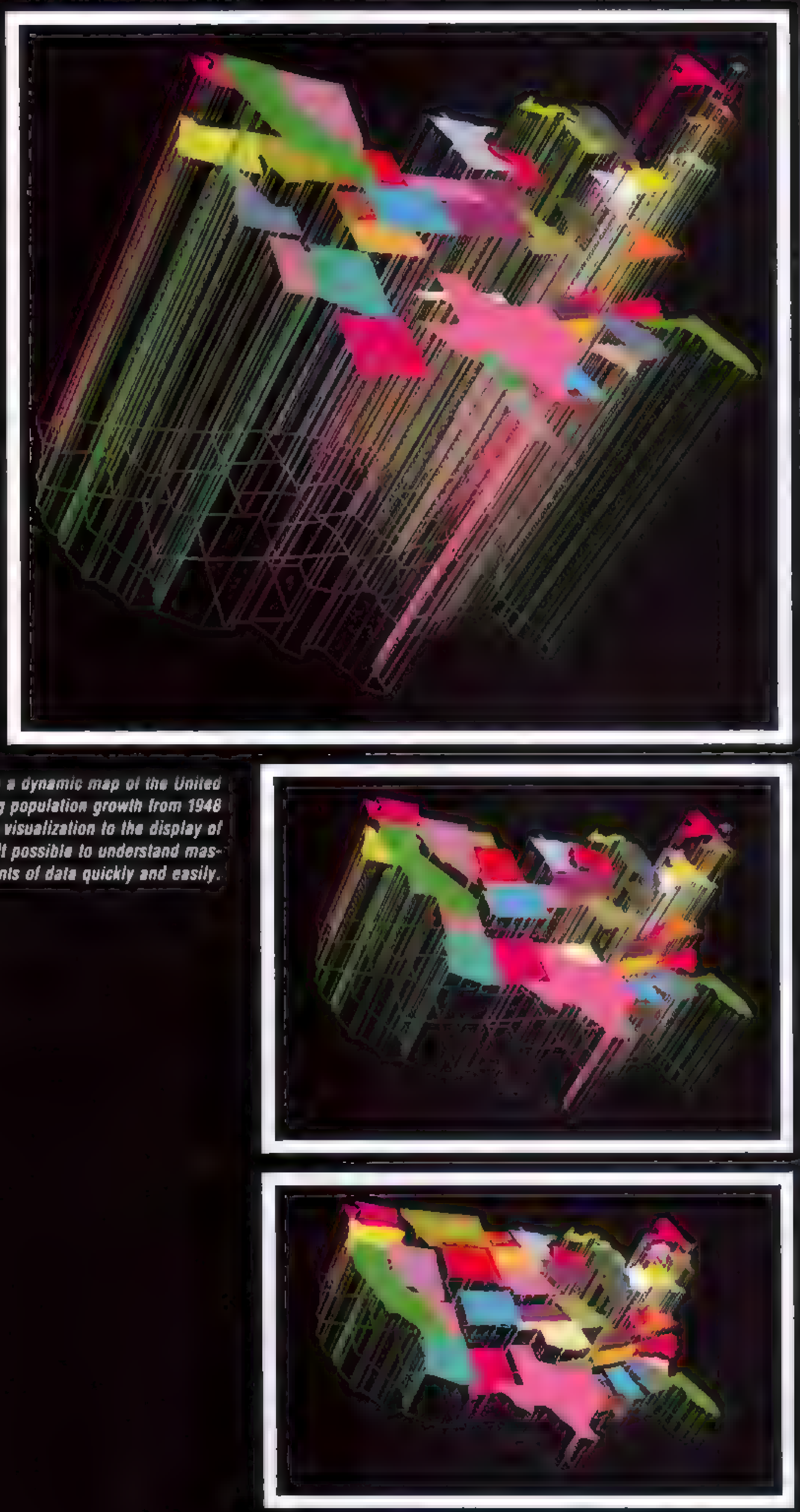
"The important thing to understand," Silicon Graphics' McCracken has observed, "is that many of the uses for these computers remain to be defined. We've often said because it's such a new field that the most popular applications for our systems have not yet been written.

"Animation, industrial design, architecture, chemistry, computer graphics, and computer science are all important areas of use for visual processing. In the near future I believe we'll see the utilization of our systems in computer-aided software engineering (CASE). People are going to want to use color graphics workstations because of the tools and advantages they offer for writing software. We also think that as our systems become less expensive, it will become more common to find engineering students using Silicon Graphics machines in much the same way they currently use PCs.

"The documents they produce will contain text, and 2D and 3D graphics. With color systems that support video, audio, and image processing, and with high-performance networks, users will have ready access to local scanning and color printing capabilities, and they'll be able to generate videos as easily as they currently print text. And I want to stress that this isn't just a dream. The technology already exists and will be commercially available sooner than you think.

"But, as I've said, it's still new technology. We have much to learn about its potential. That's why being able to put Silicon Graphics systems into the university environment is so important — we're watching, the teachers are watching, the students are experimenting, and we're all learning."

Gaye Graves is a Visual Information Specialist at NASA Ames Research Center and a contributing editor for IRIS Universe. ●



Three frames from a dynamic map of the United States illustrating population growth from 1948 to 1990. Applying visualization to the display of statistics makes it possible to understand massive amounts of data quickly and easily.

VISUALIZATION IN THE MIND'S EYE

BY THOMAS G. WEST

When the gifted essayist Lewis Thomas draws analogies between micro-organisms and an organized human society, depicts the sky as a membrane, or describes mankind as a heap of earth, he is capturing in words a kind of resemblance that may well have occurred to him initially in spatial form. Indeed, underlying many scientific theories are "images" of wide scope: Darwin's vision of the "tree of life," Freud's notion of the unconscious as submerged like an iceberg, John Dalton's view of the atom as a tiny solar system, are the productive figures that give rise to, and help to embody, key scientific conceptions. It is possible that such mental models or images also play a role in more mundane forms of problem solving.

— Howard Gardner[1]

Images and Statistics

The power of the image to embody major concepts and to reveal repeating patterns in apparently unrelated things is clearly evident in the early development of the science of statistics. The usefulness of the visual, graphic or "geometric" (right-hemisphere) approach is most apparent in the work of Karl Pearson and that of his son, E. S. Pearson. Karl Pearson is credited with being the first person, in the latter part of the nineteenth century, to apply statistics systematically to biological phenomena. He placed great store by the visual or graphic method (as opposed to merely numerical or algebraic expression). His lecture notes indicate his position:

> *Contest of geometry and arithmetic as scientific tools in dealing with physical and social phenomena. Erroneous opinion that geometry is only a means of popular representation; it is a fundamental method of investigating and analyzing statistical material.*[2]

The same perspective is set forth by E. S. Pearson, writing in the 1950s:

> *A visual survey of the "pattern" of his data provides the statistician ... with the quickest method of checking whether the model he proposes to use is likely to be appropriate or not. That understanding can be achieved through visual aids may be regarded as a proposition so obvious that it needs no restatement by me; yet there is much evidence that the average mathematically-trained student who forms today the raw material of our classes in mathematical statistics is not too well endowed with visual imagination.*[3]

Visualization: Uniquely Human

In this way, E. S. Pearson indicates how a specialty that presumably was created largely by one mode of thought may become gradually filled with those who rely primarily on another mode of thought. In defense of the one mode, he points out that the visual presentation may help the statistician in several ways:

> *In understanding the meaning of his mathematical results; in avoiding mistakes through lack of fit of his models; in saving time; and in ... making clear his methods of analysis to the non-statistician. But the prestige of mathematical procedures based on algebraic formulae is deeply entrenched in our lecture courses and our text-books, so that few mathematical statisticians will use to the full their visual faculties unless they are trained to do so.* [4]

This situation is especially regrettable because E. S. Pearson has learned from personal experience

> *That the intellectual stimulus which can come from use of the visual imagination may be very great.* [5].

After giving two specific examples of how visual presentation made complex mathematical problems "beautifully simple" to him, E. S. Pearson observes:

> *I am told that I have been fortunately endowed with an extra amount of visual imagination, and that it is unfair for me to expect others of my staff or students to be helped by statistical geometry.* [6]

Thus, it would appear that E. S. Pearson was aware that much of value had been lost in the transition from visual to exclusively mathematical analysis. It is as if one mode of thought created the discipline, but that another (relatively antithetical) mode of thought took over the discipline and cut all ligatures of connection with the source of its origins. Since one could expect the university system to select for those most proficient in verbal-logical-mathematical modes of thought and against those proficient mainly in visual-spatial modes of thought, it is not surprising that the younger Pearson found himself surrounded, eventually, by relatively alien souls.

Presumably, E. S. Pearson had inherited from his father some of the visual-spatial mind-set that originally seized upon the unconventional connections and he retained a profound respect for the power of this same mind-set to create new connections in the future. But as the unconventional became conventional, the new practitioners and professors regarded the origins as primitive and therefore regressive. This attitude is underscored by the fact that the *old* mind-set—the visual-spatial approach—often allows sophisticated concepts to be understood by ordinary people. Thus we see two of the major figures in the development of statistics arguing with conviction for greater use of the visual-spatial mode of thought.

Today, this old mind-set is becoming new once again. There is a growing trend among scientists to adopt visual modes of thought — partly because of the growing capabilities of powerful new computers and partly because of the great difficulty of dealing effectively with the volumes of information that these machines have produced.

Some years ago, reports began to appear that indicated that computer-generated multidimensional graphic displays helped scientists to detect relationships in data that would never have been detected by conventional methods. In one such report,

> *scientists at Stanford's Linear Accelerator Center (SLAC), and at Harvard University, for example, are seeing patterns in data that never would have been picked up with standard statistical techniques. The aim of data analysis is to discover patterns, to find non-random clusters of data points. Traditionally, this is done by using mathematical formulas. But, with the advent of computer motion graphics, it has become possible to look at three-dimensional projections of the data and to make use of the uniquely human ability to recognize meaningful patterns in the data.* [7]

Thus, the "uniquely human" potential of visual thought in recognizing "meaningful patterns" seems to be receiving increasingly serious attention and has begun to produce results of substance, apparently unavailable through other means.

Chaos

The increasing importance of the image as a primary focus of analysis is also seen in the recent development of the new science known as "chaos." Chaos is a loosely associated family of new analytical approaches in mathematics and science. Books and articles on chaos for the layman have begun to appear in recent years, but its associated theories have been developing for several decades.[8] According to James Gleick, the author of a recent book on the subject, *Chaos: Making a New Science*, its theory and techniques may apply equally to the historical prices of cotton, the turbulence of water, the beating of a human heart, or the behavior of clusters of stars. The development of this new discipline is of particular interest here because it has involved a clear shift of emphasis toward visual modes of thought and analysis.

There are many different definitions of chaos, but there are distinct underlying similarities.

For some, chaos is the study of mathematical patterns (hidden under apparent randomness) that can be found, especially at high levels of energy, in large and complex and rapidly-changing systems, such as global weather.

For others, chaos is the remarkable ability of surprisingly simple processes (and mathematical formulas) to generate, through massive repetition, systems (and corresponding graphic images) of great complexity.

And for others, chaos is the curious "sensitivity to initial conditions" which allows identical processes to generate very different end results because of extremely small differences in the starting points of the processes.

And for still others, chaos is mainly characterized by self similarity of mathematical (and graphic) patterns at different scales and magnitudes. These patterns are admired by some for their beauty alone. The colored images of these patterns have been reproduced widely in popular and professional scientific magazines over the last few years, so that they are becoming an increasingly familiar sight: the skewered snowman (the Mandelbrot set) or the many-tongues-of-fire, paisley-like "fractal" images—images that are, in fact, just different aspects or different views of the same pattern, since the differences are produced, so to speak, by looking into (that is, zooming in and blowing up) the edges of the same pattern deeper and deeper and deeper still again.

Chaos is not seen as serving every need, even by the strongest adherents. It is recognized that different forms of analysis are needed for different purposes. Practitioners of the new approaches want it to be clearly understood that the old ways are not being abandoned. However, the old ways have limits and the new ways are producing from fresh perspectives solutions that were thought impossible only a short time ago.

These developments are exciting in themselves, as they appear to slowly peel away, in a most unexpected and surprising manner, another whole layer of reality. But they are of interest to us mainly because of the way they shift emphasis to primarily visual modes of analysis and thought.

Thus, the developments associated with chaos suggest the beginning of an alternative trend away from traditional mathematical analysis — an alternative trend toward the analysis of images. As Gleick observes:

> *Chaos has become not just theory but also method, not just a canon of beliefs but also a way of doing science. Chaos has created its own technique of using computers, a technique that does not require the vast speed of Crays and Cybers but instead favors modest terminals that allow flexible interaction. To chaos researchers, mathematics has become an experimental science, with the computer replacing laboratories full of test tubes and microscopes. Graphic images are the key. "It's masochism for a mathematician to do without pictures," one chaos specialist would say. "How can they see the relationship between that motion and this? How can they develop intuition?" Some carry out their work explicitly denying that it is a revolution; others deliberately use ... [the] language of paradigm shifts to describe the changes they witness.* [9]

It is almost uncanny that these new developments should have resulted in views so closely parallel to the observations of the two Pearsons quoted earlier. The Pearsons knew they were seeing the relationships in the data primarily through their own unusual ability to visualize these data—relationships that could sometimes be sketched with simple graphics. In contrast, their colleagues and students pretty much kept to the mathematical symbols alone—the algebraic approach—and left the graphics to popular presentations. Presumably these colleagues were more comfortable with the disciplined logic and order of the symbolic system but had less well developed powers of visualization, as E. S. Pearson observed.

Now, however, about a hundred years after the elder Pearson's work, the tables may be turning once again, and those who work with the new tools and new concepts may be those who are far more comfortable with computer images that are occasionally translated into mathematical formulas than they are with formulas that are occasionally translated into images.

Graphics Are the Key

The Pearsons' colleagues, in the late nineteenth and early twentieth centuries, did not understand their intense interest in pictures. The chaos researcher, in the late twentieth century, cannot see how anyone can understand the relationships without pictures, especially the moving and responsive pictures produced on demand on one's computer. A powerful aid to the imagination. A complete reversal in the making.

Several trends converge. The new science of chaos has provided new mathematical tools and new ways of looking at problems that were either ignored or thought insoluble before. Whole classes of phenomena had not been dealt with previously because the mathematical tools were not available to do the job. This has changed.

But these new tools may come to require new skills and talents. With the further development of smaller, cheaper but more powerful computers having sophisticated visual-projection capabilities, we might expect a new trend to be emerging in which visual proficiencies could play an important role in areas that have been almost exclusively dominated in the past by those most proficient in verbal-logical-mathematical modes of thought. *Increasingly graphic images are the key.*

The preceding article was excerpted from Thomas G. West's forthcoming book In the Mind's Eye: Visual Thinkers, Gifted People with Learning Difficulties, Computer Graphics, and the Ironies of Creativity. *Mr. West lives in Washington, D.C. His book will be published in 1991 by Prometheus Books, Buffalo, New York.*

1. Howard Gardner, *Frames of Mind: The Theory of Multiple Intelligences.*(New York: Basic Books,1983), pp. 176-177
2. Karl Pearson, quoted in E.S. Pearson, "Some Aspects of the Geometry of Statistics: The Application of Mathematical Statistics" in *The Selected Papers of E.S. Pearson*, (Los Angeles: University of California Press, 1966), p. 252
3. Ibid. p. 252.
4. Ibid. p. 253
5. Ibid. 253.
6. Ibid. p. 254.
7. Gina Kolata, "Computer Graphics Comes to Statistics," in *Science*, Vol. 217, (September 3, 1982), pp. 919-920.
8. Following from James Gleick, 1987. *Chaos: Making a New Science* (New York: Viking Press, 1987), pp. 4-5, 11-16, 83-107, 280-292.
9. Ibid. pp. 38-39.

Modeling & Mapping

THREE-DIMENSIONAL PROPERTY DATA

BY SKIP PACK AND GENE BRESSLER

The creation of complex three-dimensional property models used to be a difficult and expensive task. Thanks to the IVM *software package that's no longer the case.*

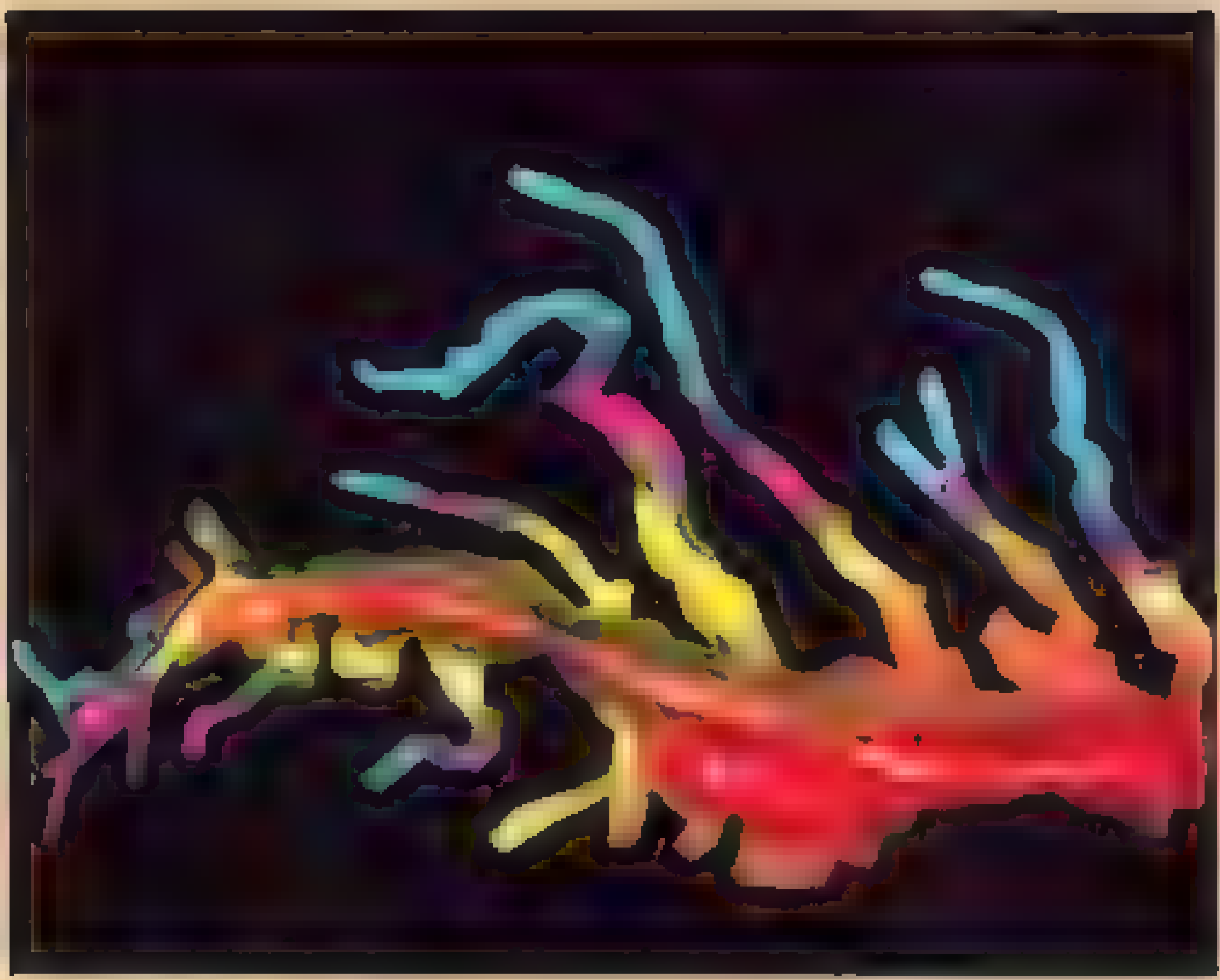
Three Dimensional Property Modeling

A few years ago, nearly all three dimensional modeling and visualization programs were lumped together and considered to be very similar. There are, however, task related distinctions between classes of systems. Just as the approaches required in remote sensing imaging systems differ greatly from those dealing with structural analysis, the modeling of *properties* which vary continuously in three dimensional volumes presents its own set of mathematical and visualization challenges.

Dynamic Graphics' *Interactive Volume Modeling (IVM)* software package exploits the power and 3D graphics capabilities of the Silicon Graphics' IRIS 4D series making possible the computation and graphic display of complex three dimensional property models. The primary applications of three dimensional property modeling are the display and analysis of natural phenomena such as: the distribution of temperature in air; salinity in seas; and porosity, permeability, or chemical concentration in subsurface rock. Of significant interest to scientists and engineers studying these properties are questions such as:

- What is the character and spatial distribution of these properties within their medium: air, water or rock?

1.



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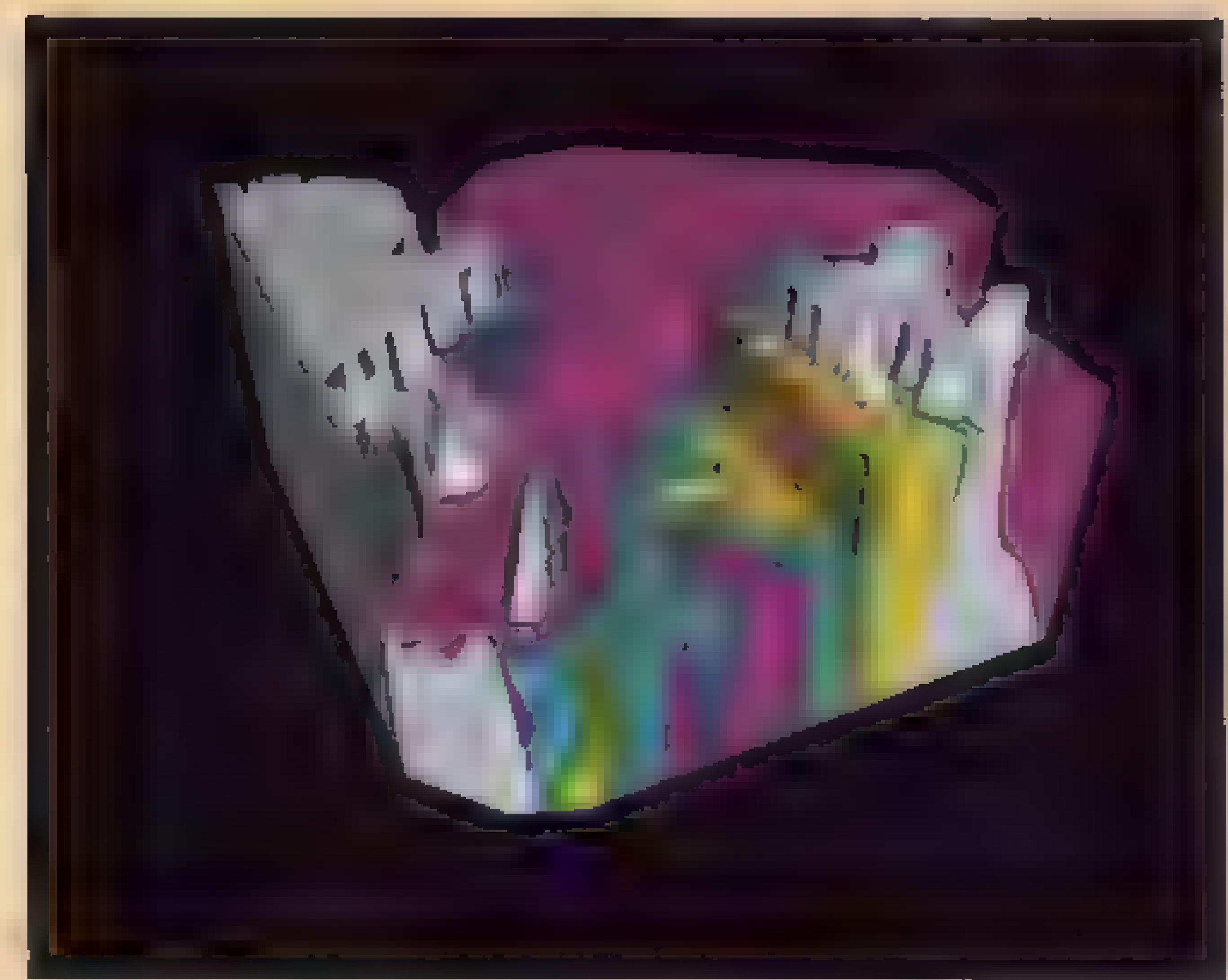

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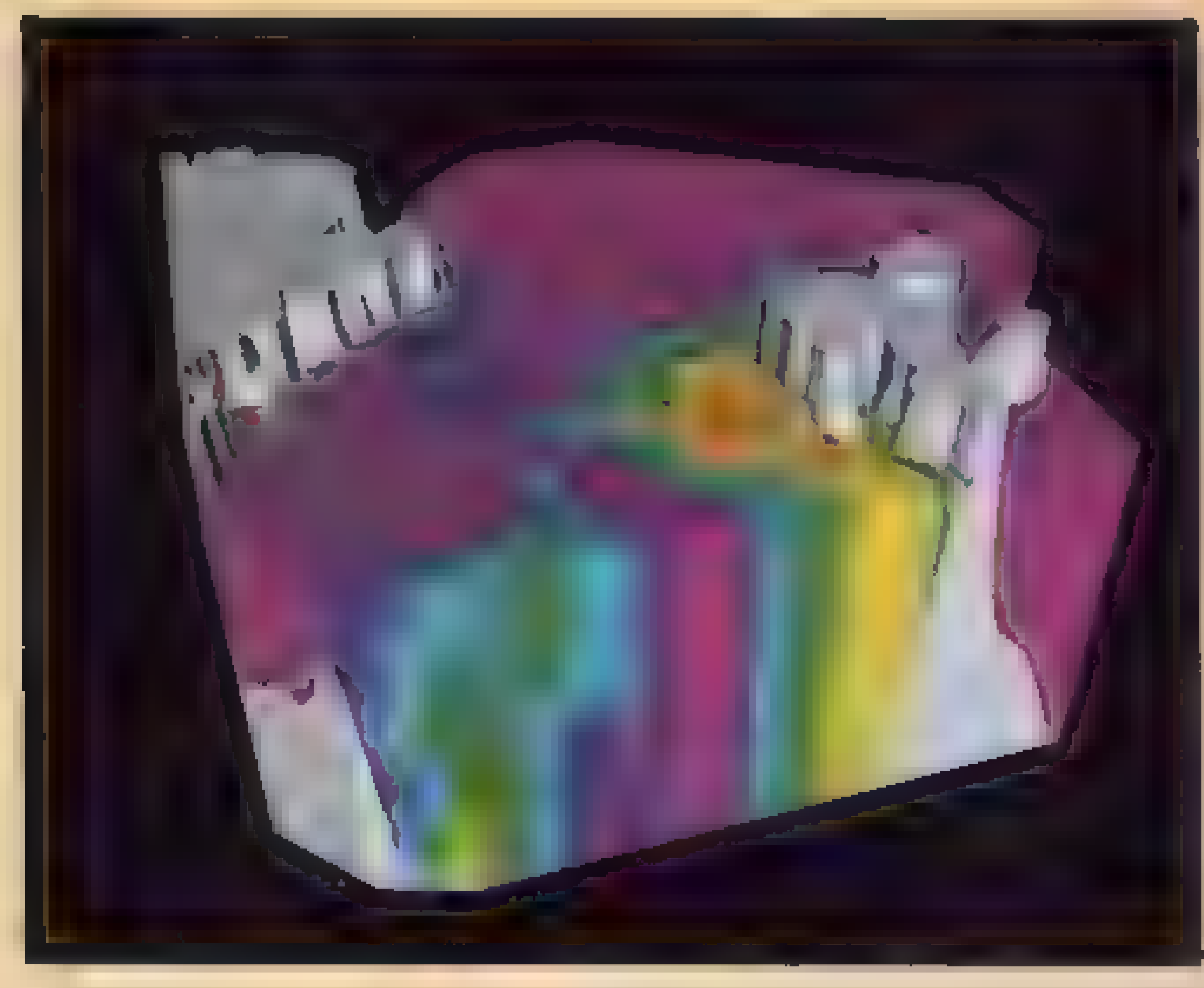


1. CHESAPEAKE BAY SALINITY
(Data Courtesy of Army Corp of Engineers, Waterways Experimental Station)
2-3. FRAM STRAIGHT
(Data Courtesy of Dr. Thomas Manley, Marine Research Corporation)

- How much of a given property or specified subset of the property exists within a defined volume? For example, how many cubic yards of overburden having a selenium concentration greater than 0.2 parts per million are there in the study area?
- What is the correlation of a given property between one zone and other zones? How does the selenium distribution in a shale zone compare with the sand zone below it?
- How do various properties relate to and affect the characteristics of another property? For example, how do the characteristics of porosity and permeability influence the concentration of selenium in an area?

In short, the three dimensional modeling approach developed by Dynamic Graphics is appropriate for any characteristic which is more naturally modelled as continuously varying throughout a region, rather than existing as a three dimensional network of discrete values. The challenge for the developers of appropriate software tools, therefore, is to enable users to understand the character of the property and interactively interpret property values in locations where these values are not available.

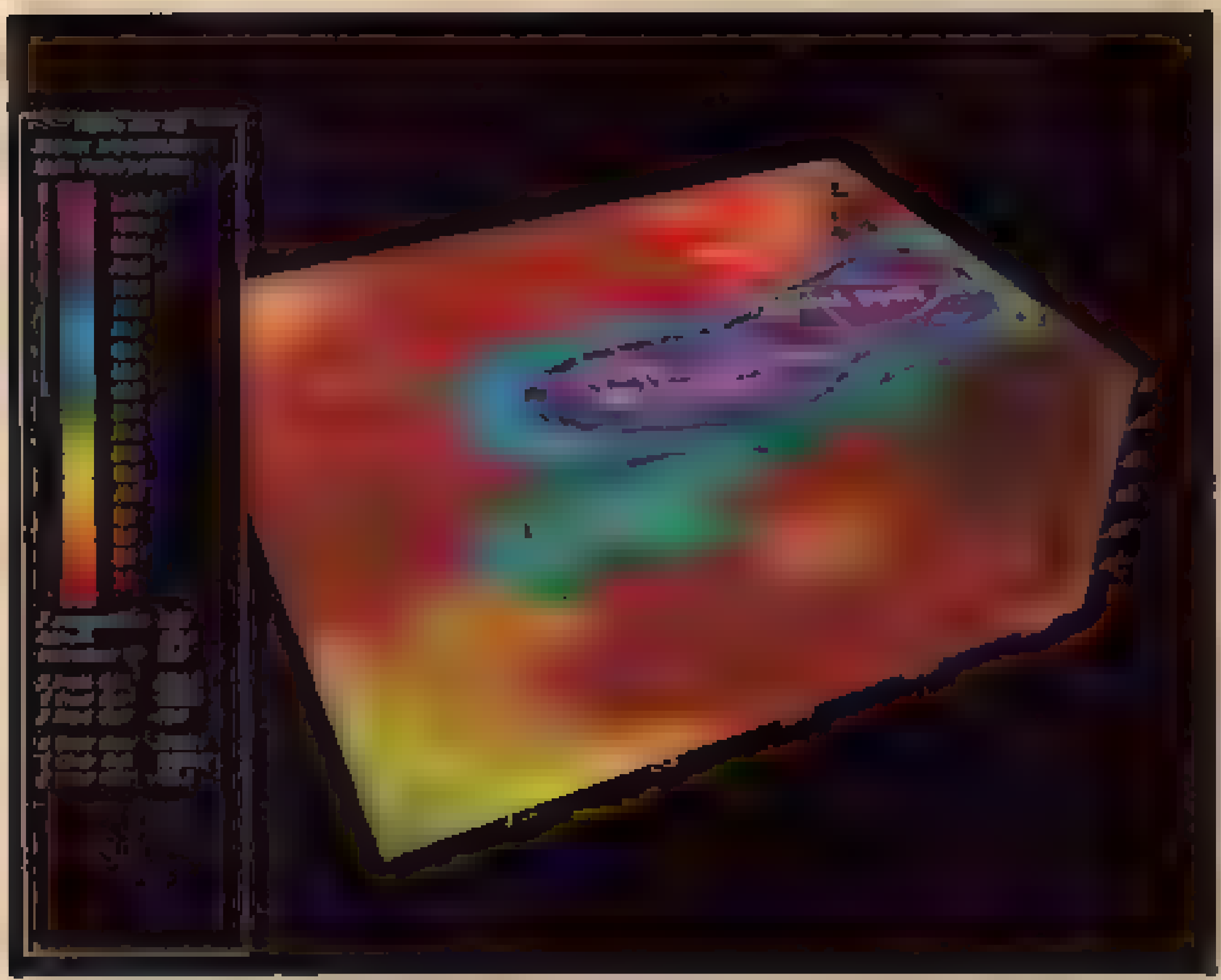
Interactive Volume Modeling (IVM)

IVM offers users combined modeling and visualization tools to view complex three dimensional data relationships and perform analyses heretofore not readily possible. *IVMCalc*, the modeling component, utilizes scattered data (georeferenced X, Y, Z and P, where P is property value data) to produce a three-dimensional volume grid model. Using this grid model, the user builds a three dimensional graphic display file containing the three dimensional isovalue surfaces at selected data levels. With *IVMDraw*, the graphic component, the user manipulates the three dimensional model in real time with techniques that include: iso-peeling, slicing and rotating. Supplemental map annotation, showing roads, property boundaries, land use and other cultural information can be added. Analytical operations include: three dimensional volumetrics, trend gridding, grid operations, back interpolation, model editing and two dimensional surface/structure map extraction, and property model truncation by complex surfaces. A three dimensional cursor enables data extraction and the drawing of lines, such as curved well paths as often occur in oil exploration.

Chesapeake Bay and its Tributaries

The U.S. Army Corps of Engineers, Waterways Experiment Station (WES), Vicksburg, Mississippi is using *IVM* to visualize hydrodynamic models of various properties including salinity and temperature in the Chesapeake Bay. The Corps, using an internally developed numeric model created volumetric grids of temperature and salinity, representing changes at five minute intervals for a full year (more than 105,000 grids in all). In the accompanying figure, *IVM* was used to display the property, salinity, occurring within a vol-

4.



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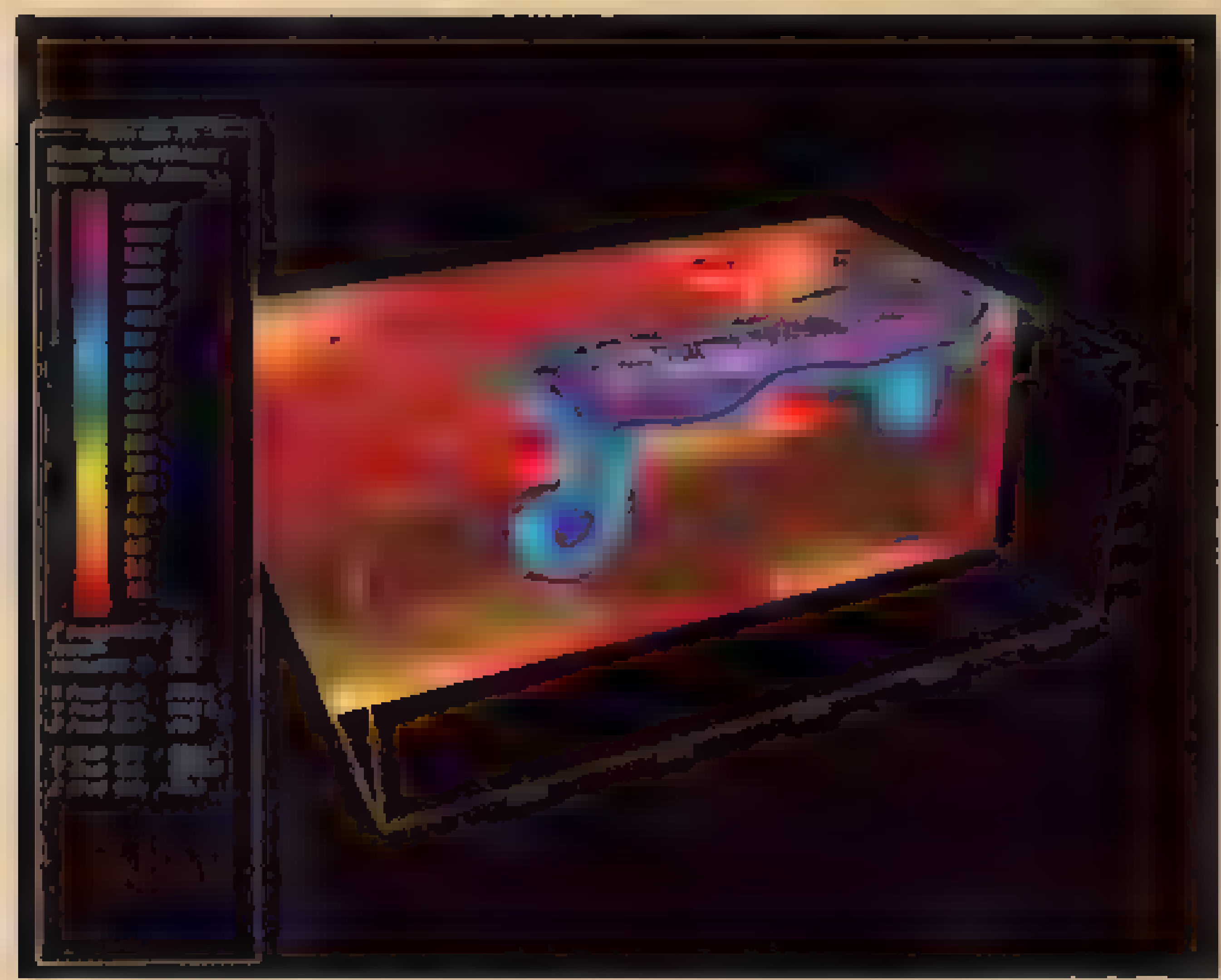

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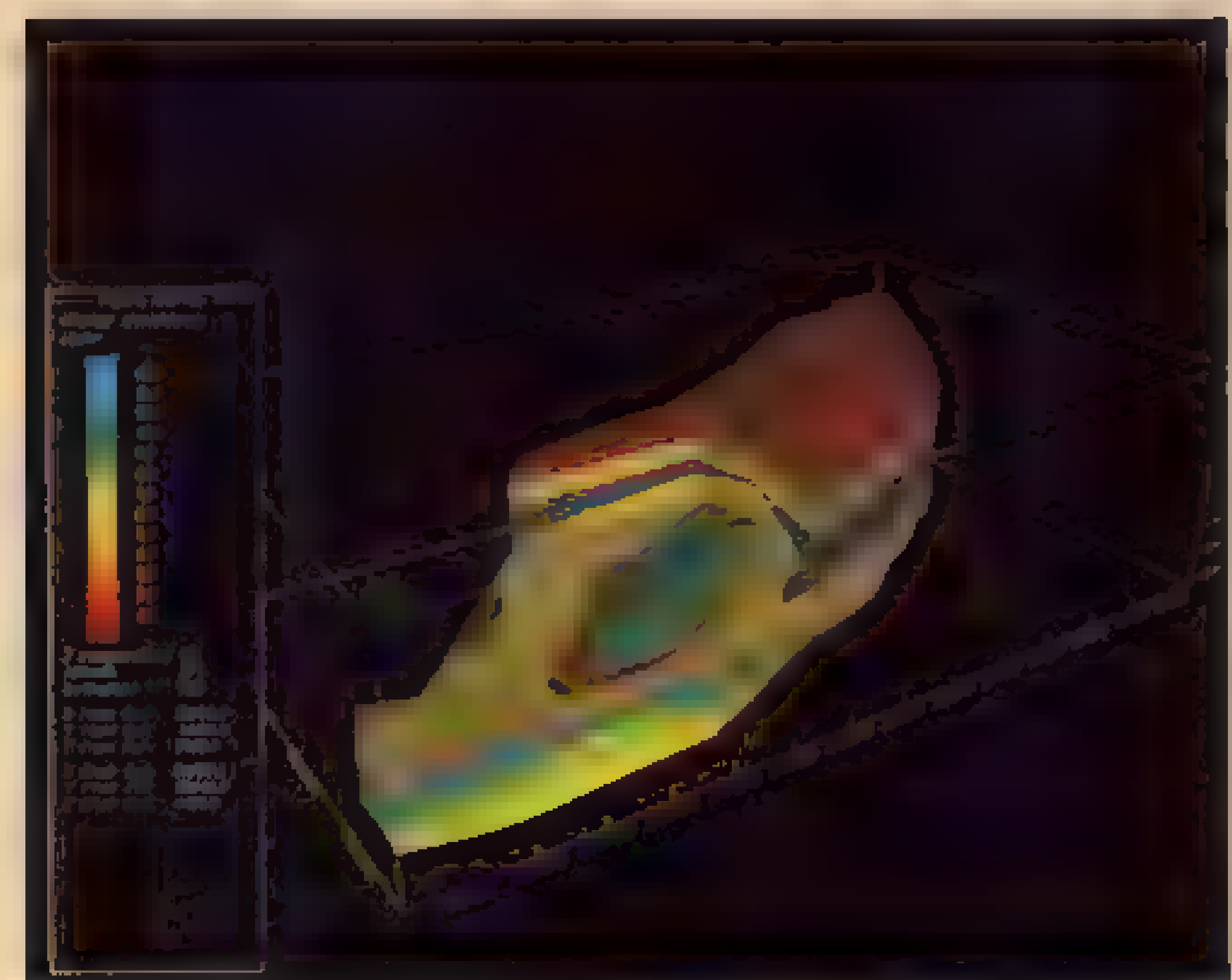


4-5. PCE CONCENTRATIONS
(Data Courtesy of Lawrence Livermore National Lab)
6. MULTI-ZONE RESERVOIR POROSITY

ume defined by the bay bottom and top surface water level. Displays of a number of time slices were captured and combined to produce an animated sequence of salinity changes over a significant rainfall event.

Temperature in the Fram Straits

Oceanographers from the Lamont Doherty Geological Observatory collected temperature, salinity, and density data from the Fram Strait area located near Greenland over an eleven year time span in an effort to understand the dynamics of the mixing of the North Atlantic Current and the Arctic Ocean. In the two examples shown here, the warmer (yellow to red) waters of the North Atlantic Current can be seen circulating along the western margin of Spitsbergen Island on the right. The model confirmed the theory that much of the Atlantic water never reaches the Arctic but is instead recirculated back towards Greenland. This information is useful for studying the effects of water masses on weather patterns and determining the acoustic properties of this strategically important submarine transit track.

Soil and Ground Water Contamination

Scientists in the Environmental Restoration Group of the Lawrence Livermore National Laboratory (LLNL), California are using *IVM* in their site characterization and remediation efforts. At issue is the contamination of ground water and soils by the chemical PCE. LLNL collected data from over 300 wells, comprising 425 soil and water samples. *IVM* was then used to spatially model PCE within its geologic context. Shown here is a PCE plume model, delineating the overall extent of PCE with concentrations greater than 80.0 parts per billion. The correlation of these models enables LLNL's scientists and engineers to predict likely migration paths for the plume, determine where to place additional sampling and monitoring wells and to construct an efficient restoration system.

Properties Occurring Within Various Subsurface Rock Zones

Geologists and reservoir engineers involved in oil exploration are using *IVM* to model subtle changes in porosity and permeability within oil bearing sand. The goal is efficient management of oil reserves and application of appropriate techniques for enhanced recovery. In this example, porosity variations occurring within a series of sand beds were combined within intervening shale layers. By slicing through the structure and stripping out individual layers, it is possible to determine whether the sands are continuous sheets or discrete lenses, and if there is "communication" between producing zones and to detect the occurrence of effective barriers.

Skip Pack is Product Manager and Gene Bressler is Director of Marketing and Applications Planning for Dynamic Graphics, Inc., Alameda, California. Additional contributions were made by Jim Tallet and Rob McFaul also of Dynamic Graphics, Inc.

DESIGNER'S WORKBENCH

POWER & SOPHISTICATION

Designer's Workbench (DWB) gives you the power of a 3D graphical editing and animation system and the sophistication of an interactive, integrated environment.

Easy to Use

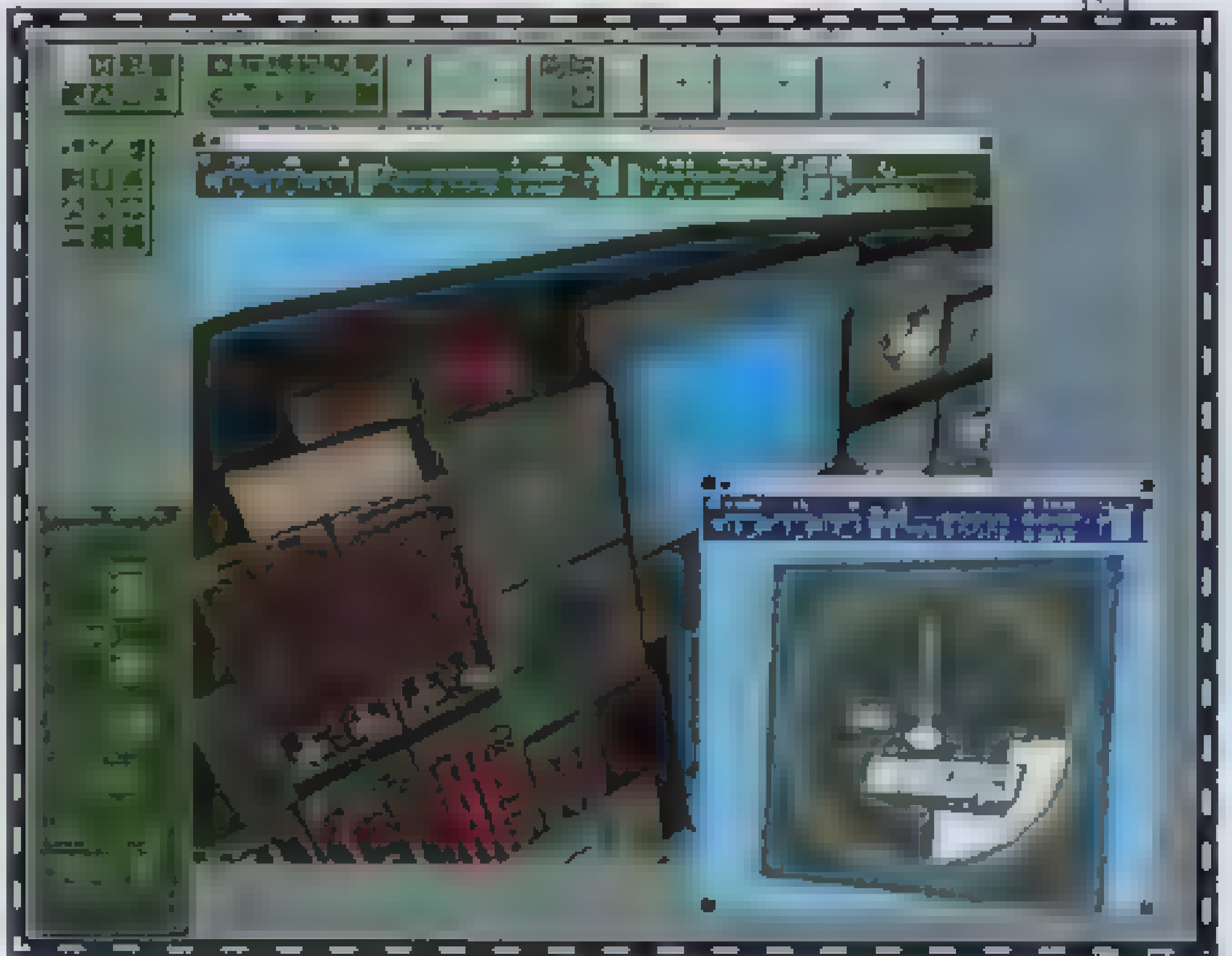
You can quickly create, edit and test your displays using an intuitive, mouse driven user interface.

Compatible

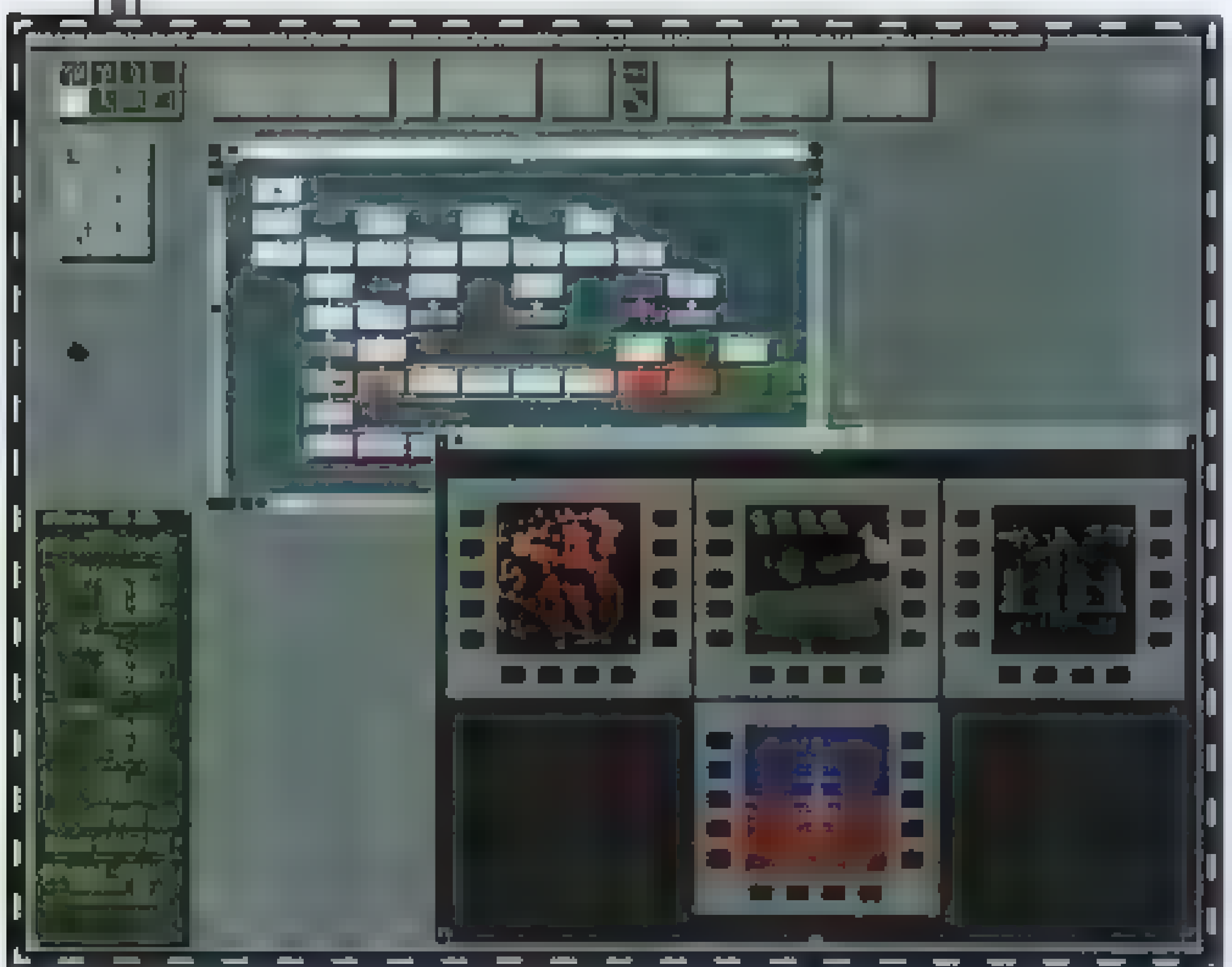
Data base files created with DWB can be displayed and animated outside the editing environment with:

- The DWB Real-Time Module
- Gemini Technology's GVS SIMation Series™
- Your own real-time software and hardware

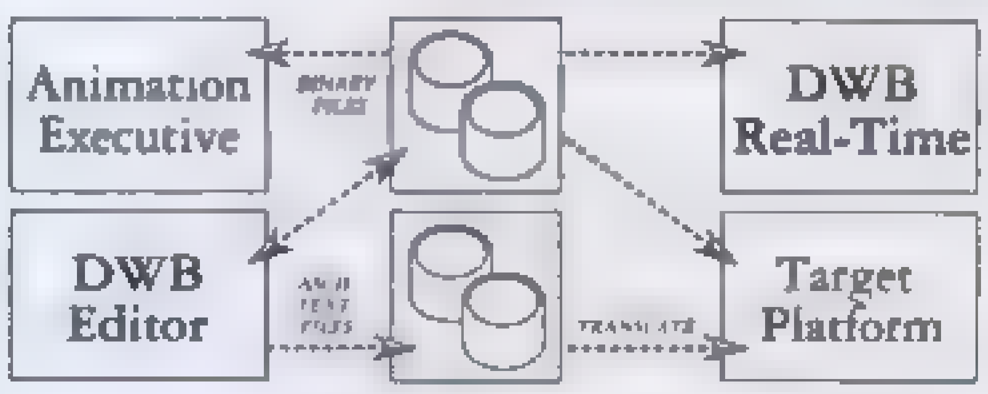
Code generation for other target system hardware (avionics, user-supplied simulation, etc.) can be accomplished by selecting and outputting geometry and attribute data in ASCII text format.



Data base courtesy of the Army/NASA Aircrew-Aircraft IntegrationProgram and S-Systems, Inc.



Data base courtesy of General Dynamics, Ft. Worth Division



2D and 3D Perspective Displays

DWB can emulate display devices that have both 2D and 3D perspective pages. Overlays on 3D perspective pages are possible as well. 3D polygonal terrain can be automatically generated from DMA DTED source data for use in display device pages.

Data Base Optimization Tools

DWB lets you directly edit the structure of your data bases so that elements can be conveniently grouped for selection or animation. You can also optimize the run-time performance of data bases by tagging elements as static or dynamic.

Designer's Workbench runs on the complete line of Silicon Graphics Workstations. For more information, contact:

Coryphaeus Software

17991 Rose Ct., Monte Sereno, CA 95030

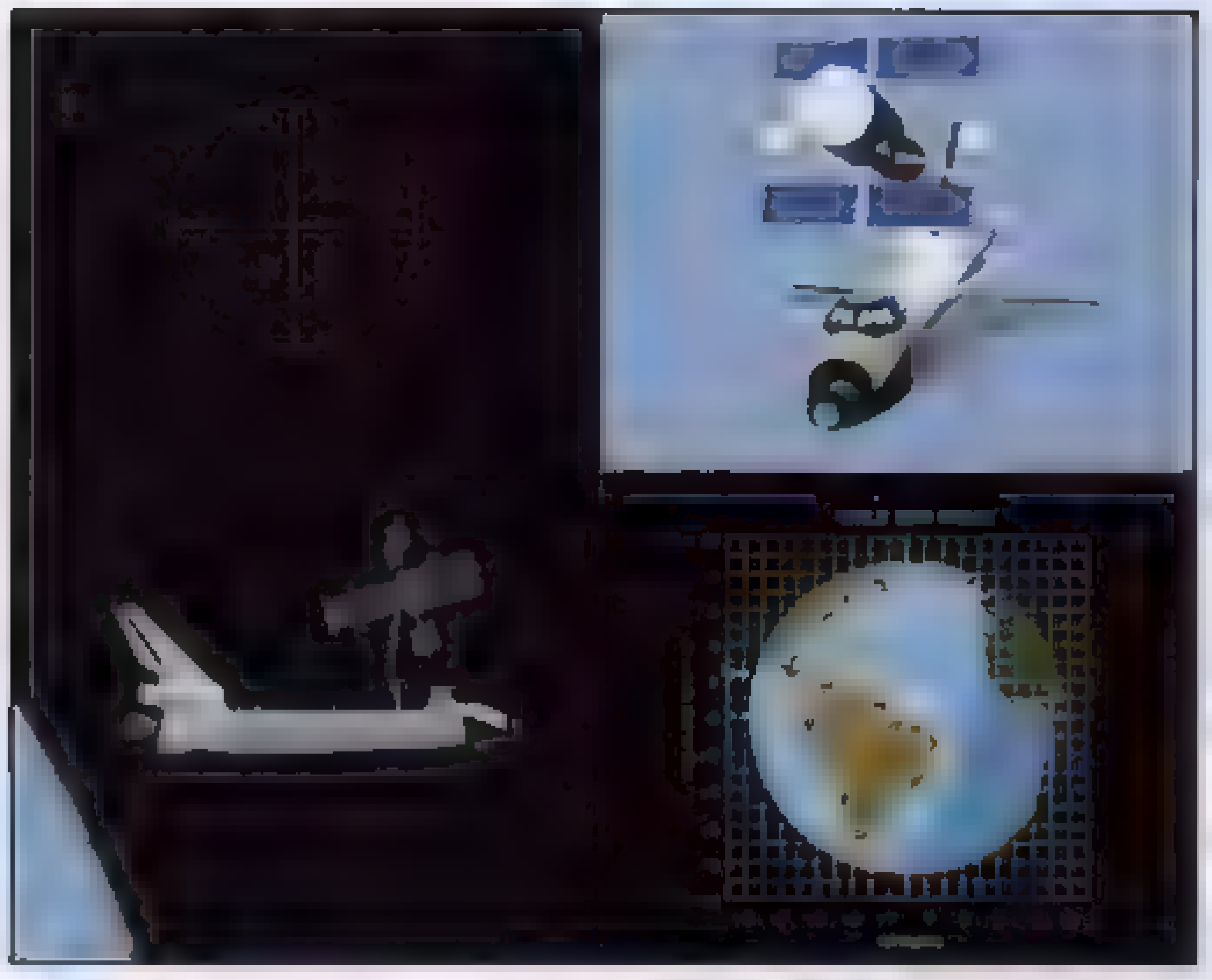
Phone: 408-395-4537 Fax: 408-395-6351

BEING THERE

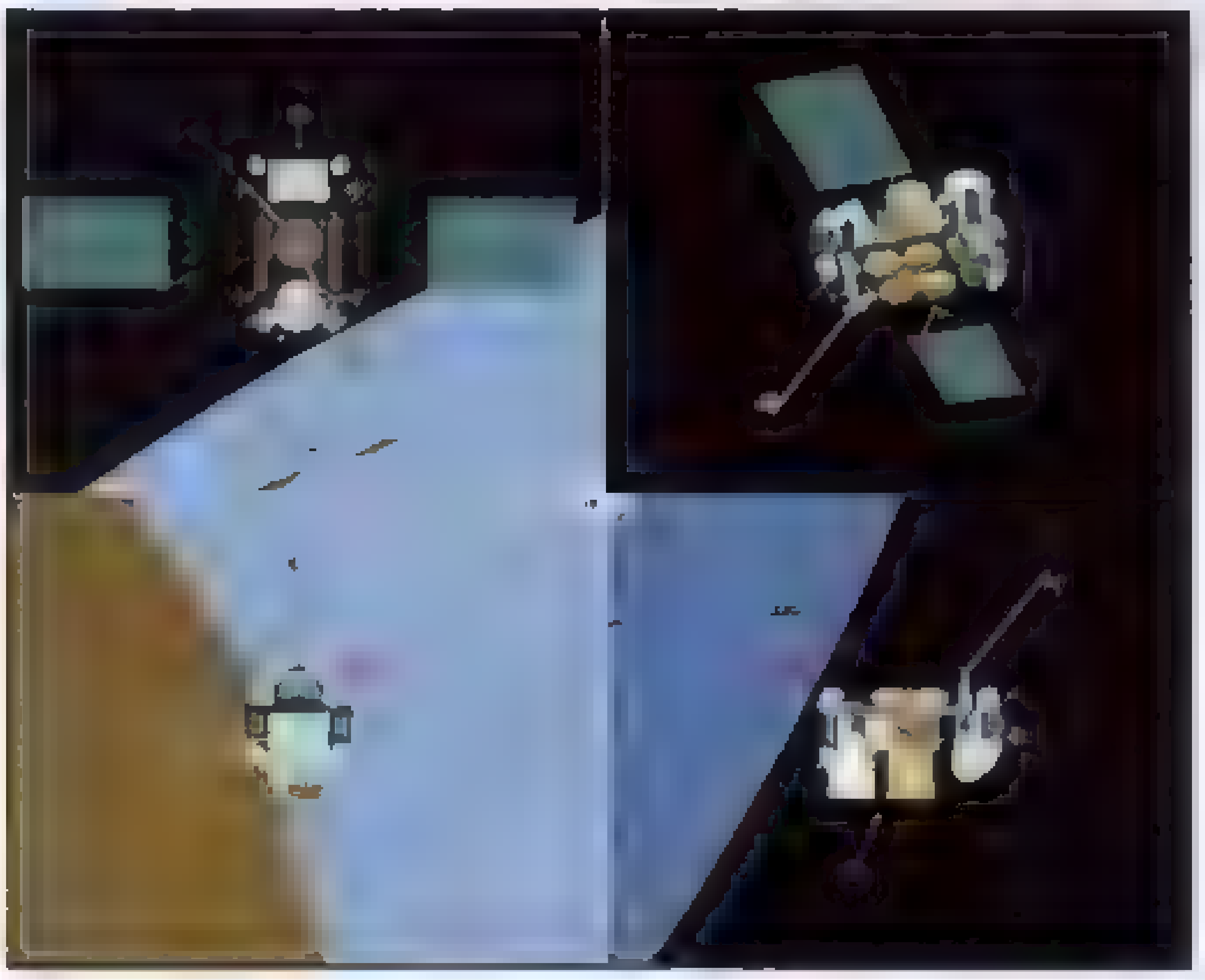
Using a specially developed three-dimensional monitoring system, NASA has automated real-time visualization of the Space Shuttle and other spacecraft missions.

BY JAMES F. JELETIC AND ERNEST J. PITTARELLI

Above
The operations area of NASA Goddard's Flight Dynamics Division uses real-time computer graphics to monitor the shuttle's retrieval of the Long Duration Exposure Facility



Left: The 3D-Mon system provided various views of the Hubble Space Telescope deployment during periods when live video coverage was unavailable. Along with views of the spacecraft, the system is capable of providing other unique views, including the view of a Tracking Data and Relay Satellite (TDRS) as seen from the Shuttle's Ku-band antenna (upper left quadrant) and a view of the Shuttle and earth as seen from a TDRS (bottom right quadrant).



Left: The Gamma Ray Observatory (GRO) will use 3D-Mon software to support its launch in November of 1990. 3D-Mon will be used to monitor GRO's orientation with respect to the sun and other items of interest. The upper right quadrant displays a perspective view of the spacecraft.

During mission operations, a majority of the work performed at the National Aeronautics and Space Administration (NASA) involves monitoring the health and safety of a spacecraft and determining the cause of any anomalous behavior by that spacecraft. Often, the most effective means of accomplishing this is by visually monitoring the spacecraft and its components.

In reality, this technique is almost never feasible since video cameras cannot be located at the viewpoint needed for study and astronauts are not usually in the vicinity to conduct visual examinations. Therefore, analysts must rely on telemetry data received from the spacecraft and other related parameters. This information is processed and then used by analysts to produce mental images of the spacecraft in its surrounding environment. This computationally intense and mentally demanding process must often be completed quickly to ensure the safety of the spacecraft and its occupants (if any), the integrity of its data, and the successful completion of the mission.

With the rapid advance of computer graphics technology, the Flight Dynamics Division at NASA's Goddard Space Flight Center has been able to significantly enhance the analyst's capabilities by automating the visualization process. The result has been the development of graphics systems driven by real-time spacecraft telemetry data that accurately emulate a spacecraft in its surrounding environment.

Emulation Capabilities

The first of these systems, the Flight Dynamics/Space Transportation System 3-Dimensional Monitoring System (3D-Mon) has been operational since 1986. The primary objective of 3D-Mon is to compute and display an accurate 3D solid model of the Space Shuttle, its appendages, its payload, and its surroundings from real-time spacecraft telemetry data (received at intervals of two to ten seconds).

The 3D images generated by the system contain a solid, flat-shaded Shuttle with shading based on light sources at the sun and/or the viewpoint. The position and orientation of the Shuttle, payload, robotic arm, cargo bay doors and Ku-band communications antenna are derived from real-time Shuttle telemetry data.

In addition to depicting the Shuttle itself, the images accurately depict the Shuttle's environment. The earth is displayed in its accurately scaled size and position. The sun, moon and planets are represented as 2D icons. Their positions are based on ephemeris files that precisely predict their locations. The sun and moon may also be displayed to scale, with lunar phases (full moon, crescent moon, etc.) displayed upon request. Other celestial objects (galaxies, quasars, etc.) can be represented as alpha-numeric characters. Stars are rendered as groups of pixels whose sizes are varied proportionally to the brightness of the star. Vectors may also be added that represent the direction of the sun, earth, spacecraft velocity, and other targets of interest to provide a relative indication of motion with respect to the universe.

Along with the generation of images in near real-time, 3D-Mon enables the user to change the viewpoint, to query an object for information, and to toggle the display of objects on or off. The user can also review a past event in a playback mode in which the update rate is controlled interactively.

The ability to support spacecraft other than the Shuttle has also been incorporated into the 3D-Mon system. Since the system became operational in 1986, it has been used to support the deployment of the Hubble Space Telescope, the retrieval of the Long Duration Exposure Facility, the early mission phase of the Cosmic Background Explorer, and maneuvers of the Earth Radiation Budget Satellite. It has requirements to support several up-

coming missions, including the Gamma Ray Observatory and the Upper Atmosphere Research Satellite.

Distributed Processing

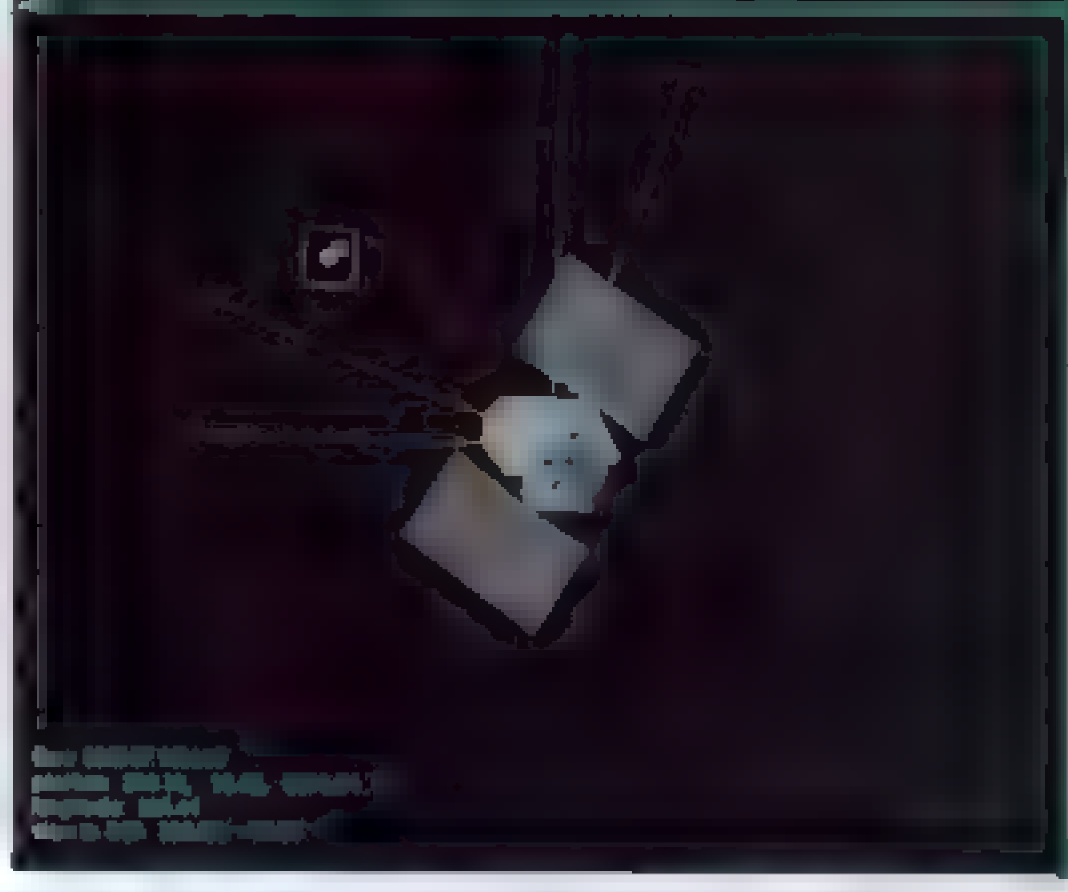
The 3D-Mon system is a distributed processing system. Telemetry data are received and processed on a National Advanced Systems 8063 (IBM 370 architecture) mainframe computer executing under the MVS/XA operating system. The processed data are then transmitted over an asynchronous 2400 baud serial communications line to a Silicon Graphics IRIS 4D/60GT graphics workstation. The software on the IRIS then converts the data into 3D images.

The IRIS-resident software consists of three major subtasks that execute as concurrent UNIX processes — communications, user interface, and display generation. These subtasks are monitored by a parent task and they communicate with each other via UNIX pipes. This multitasking approach allows the receipt of data and updating of the display to occur simultaneously. This approach also allows the screen to be updated while a user interactively selects system options from a set of popup menus and dialog boxes.

Graphics Techniques

Standard graphics algorithms and structures are incorporated in the 3D-Mon source code. These include: flat light source shading algorithms; a combination of backface and z-buffering hidden surface removal; and hierarchically designed objects to facilitate efficient transformation sequences for the Shuttle, its robotic arm and its Ku-band antenna.

Due to strict timing constraints, various techniques have been incorporated to increase performance. For instance, to improve image refresh time, the earth is drawn as a 2D disk with landmasses overlaid. Day/night shading is then accomplished by using one bitplane as a mask. All pixels in the bitplane that correspond to the area of the earth which is not in sunlight are set to one. This decreases the intensity for the shadowed portion of the earth by mapping the color of that area to a dimmer color in the color look-up table. This method is also employed to show shading of spacecraft orbit tracks.



Above, Top: SatView uses a celestial sphere to indicate the relationship of celestial objects to a spacecraft. In this particular image, SatView supports the Solar Maximum Mission (SMM) by projecting the fields of view of the SMM instrumentation onto the sphere. The green axes indicate the coordinate system of SMM while the yellow axes display a reference frame of interest (the sun's coordinate system).

Above: The Cosmic Background Explorer (COBE), launched in November of 1989, used 3D-Mon to support its initial attitude maneuvers.

Left, Lower: Of particular interest to SMM was a prediction of a solar eclipse that could potentially affect the spacecraft's power generation subsystem. SatView was used in a mission planning mode to confirm this prediction. The green rectangle in this image depicts that partial solar eclipse as seen from SMM's fine pointing sun sensor.

Celestial Views

A second system, the Satellite Viewing System (SatView) has also been developed by the Flight Dynamics Division. SatView presents data in abstract perspectives, such as a view of the sky as seen from outside the universe.

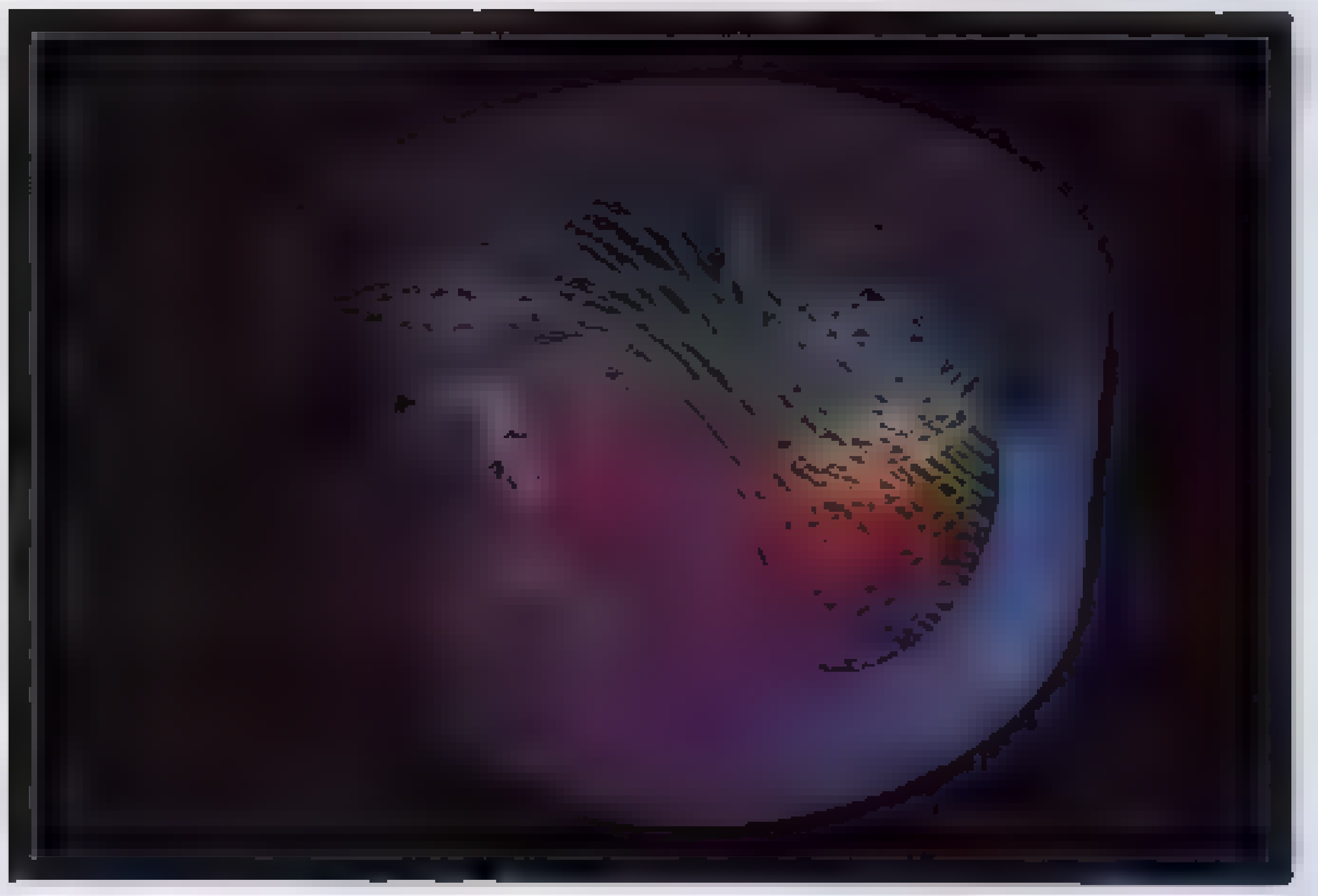
This perspective is achieved by displaying the sky as a 3D sphere surrounding the spacecraft. The sun, moon, stars, planets, and the earth's outline are mapped onto the sphere. The spacecraft is represented as x, y, and z spacecraft body coordinate axes whose origin is at the sphere's center. Sensor and instrument field of view outlines are drawn on the sphere to indicate the celestial objects that are within their respective fields of view. The user can interactively alter the viewpoint to monitor the spacecraft from anywhere outside the sphere.

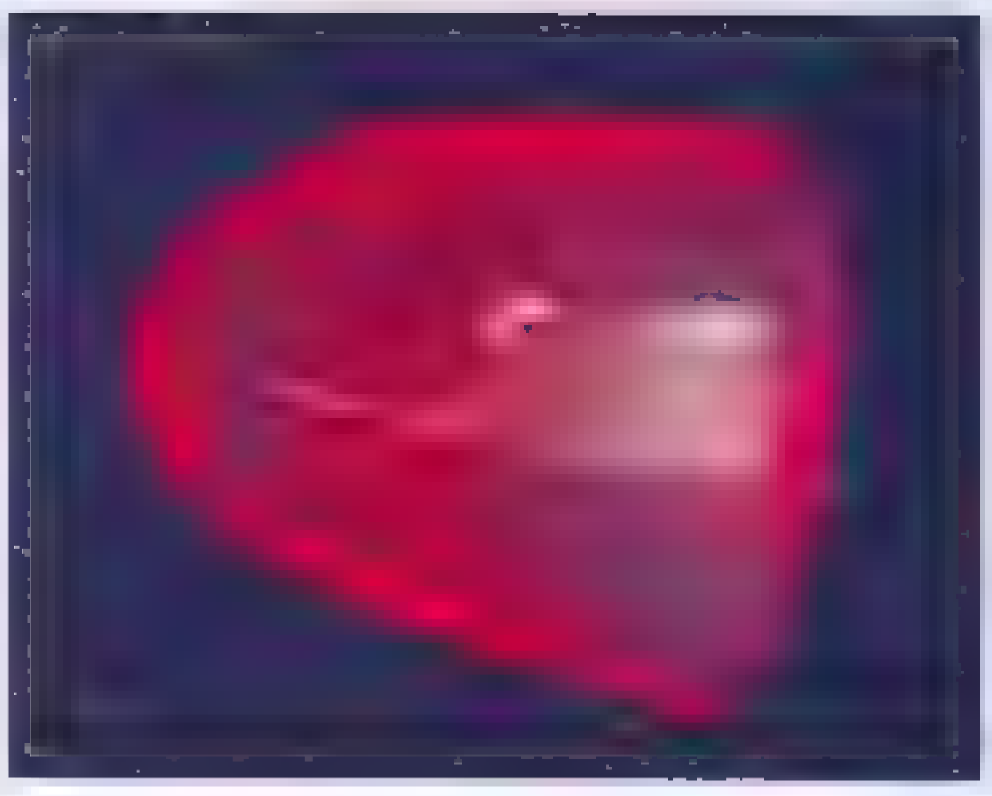
The architecture of SatView is a distributed processing system similar to 3D-Mon. The data are processed on the NAS 8063 and transmitted to the IRIS 4D/60GT workstation for graphical display.

Continual Enhancements

These emulation systems will be undergoing additional development to incorporate new analytic and graphics capabilities and to improve the image update rate. To achieve this, the IRIS workstations will be upgraded to the GT series. The next release of the software will include Gouraud shading and hardware lighting. Additional graphics capabilities, including shadowing, texture mapping and reflection, will be incorporated in future releases.

James F. Jelectic directs the development of computer graphics software for the Flight Dynamics Division at NASA's Goddard Space Flight Center. Ernest J. Pittarelli is the computer graphics project leader for the System Sciences Division of Computer Sciences Corporation.





Top: CFD technology used to compute flow in the space shuttle main engine was applied to study hemodynamics in the artificial heart. Taken from an animation, this image shows particle traces depicting blood flow through the artificial heart's main chamber and valve. Right: A network of millions of discrete points is created to simulate the flow of liquid or gas over a geometry.

Seeing Computational Fluid Dynamics

A new film recorder is being used to create stereo animation of CFD simulations.

BY KIM SNUGGERUD

The space shuttle main engine and an artificial human heart have at least one thing in common: computational fluid dynamics (CFD). CFD is the application of computer technology to simulate and study the flow of gas or liquid. It is used at NASA Ames Research Center in Mountain View, California to understand the action of fluids in relation to aerodynamic bodies, such as aircraft components and rocket engines. It has been used to compute flow in the space shuttle main engine, then applied to study thermodynamics in the artificial heart developed at Pennsylvania State University. The results have been improved knowledge and design of the artificial heart for university researchers and new understanding and technology for NASA Ames.

CFD techniques, many of which are developed at NASA Ames, have applications in aeronautics, automobile design, medical devices, thermodynamics, and geophysics — wherever the effects of gas or liquid flows are significant. One of the most important steps for interpreting CFD results is scientific visualization of the data.

Data into Images

Working from data that represents the geometry or body to be studied, a three-dimensional grid is built in the space where flow will be simulated. This identifies thousands (sometimes millions) of grid points within the 3D space (Figure 1).

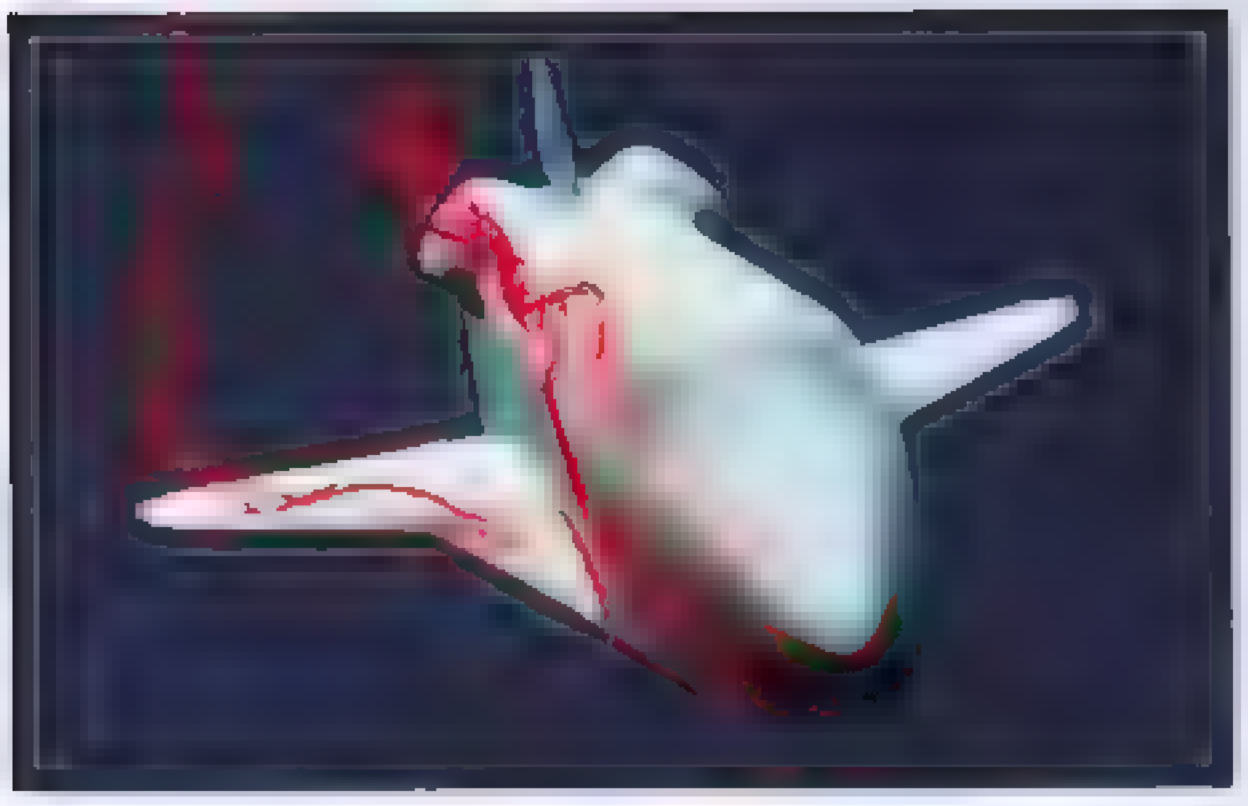
The next step is to solve fluid equations for velocity, temperature, and pressure at each discrete point using a high-speed processor, typically a supercomputer. This results in a very large data set. From this data set, graphics processing is performed by NASA using Silicon Graphics IRIS 4D workstations and scientific visualizations are created to render the numbers meaningful.

At NASA Ames, scientific visualization often results in three-dimensional animation of pressure, temperature, or velocity within or near the space occupied by an aircraft or aerospace component. However, not limited to aerospace applications, scientific visualization may involve visualization of most flow applications.

Visualization and Recording Techniques

"The visual display of complex CFD solutions currently is the most effective and efficient method of transferring complex information from computational results to the scientist," says Stephen Robinson, a research scientist in experimental fluid dynamics at NASA Ames Research Center.

Employing IRIS 4D workstations, computer graphics specialists at Ames use several post-processing programs to develop three-dimensional simulations from CFD data. These programs include PLOT 3D, SURF, and GAS, all developed at Ames and available through NASA COSMIC. PLOT 3D is a



Top: This image was taken from an animation that simulates trails from the space shuttle created to study smooth and turbulent flow.

Bottom: Pressure contours show shock wave interaction on the space shuttle orbiter, external fuel tank, and rocket boosters. Higher pressures are represented by warmer colors.

(Photos courtesy of NASA Ames: Chris Gong. Taken with the Focus Graphics ImageCorder PLUS.)

multi-function graphics program for interactive examination of fluid dynamics data. SURF has much of the functionality of PLOT 3D, plus the ability to do interactive shading and function mapping. GAS is an animation program that accepts output from PLOT 3D and SURF for object enhancement, title or label creation, viewing, animation, and recording.

Computer graphics specialists from the Ames Workstation Applications Office (Code RFW) have recently begun to develop stereo animation from CFD studies. Stereo viewing greatly enhances the ability of scientists to comprehend complex three-dimensional flow data that would otherwise be very difficult to interpret. Two stereo films produced by NASA Ames were featured at ACM Siggraph'89. Each film was created out of stereo-pair animation; one animation segment was created for the left eye view and another for the right eye view. Automatic features of GAS software were used to create the stereoscopic pairs. The animations were then recorded on 35-mm film from a Focus Graphics film recorder.

Film recording is the preferred method for recording scientific animation such as CFD. The alternative, video transfer using a scan converter, is less desirable due to significant loss in image definition and color reproduction. A scan converter brings the bandwidth down to 4 MHz from 100 MHz for a typical high-resolution graphics workstation. The subsequent dropout in color and resolution is usually unacceptable to the scientist or engineer. With the film recorder, there is no loss in definition in the recording process, resulting in an image twenty-five times more accurate (more closely resembling the original data) than video. In addition, film can be easily edited and transferred to videotape.

Two types of film recorders are available for recording animation: raster-driven film recorders and video-driven film recorders. Raster-driven film recorders offer slightly higher definition output than video-driven film recorders. The tradeoff, however, is much longer image generation and recording times. Video-driven film recorders require no software interface and will accept images at the standard 1280 by 1024 display resolution. Image generation and recording times are much faster. For example, using a video-driven film recorder, repainting and recording an image takes an average of twenty-five seconds per frame or nearly twenty hours to record 3000 frames (about two minutes of film). For a raster-driven system, each image rendered at 2000 lines takes at least two minutes to regenerate and two minutes to record for a total of four minutes per frame or 200 recording hours—nearly ten times longer.

Given its impressive performance times, NASA Ames selected a Focus Graphics film recorder for their graphics work. Paul Kelaita, a computer graphics specialist at Ames, says that when the Silicon Graphics IRIS went to high-resolu-

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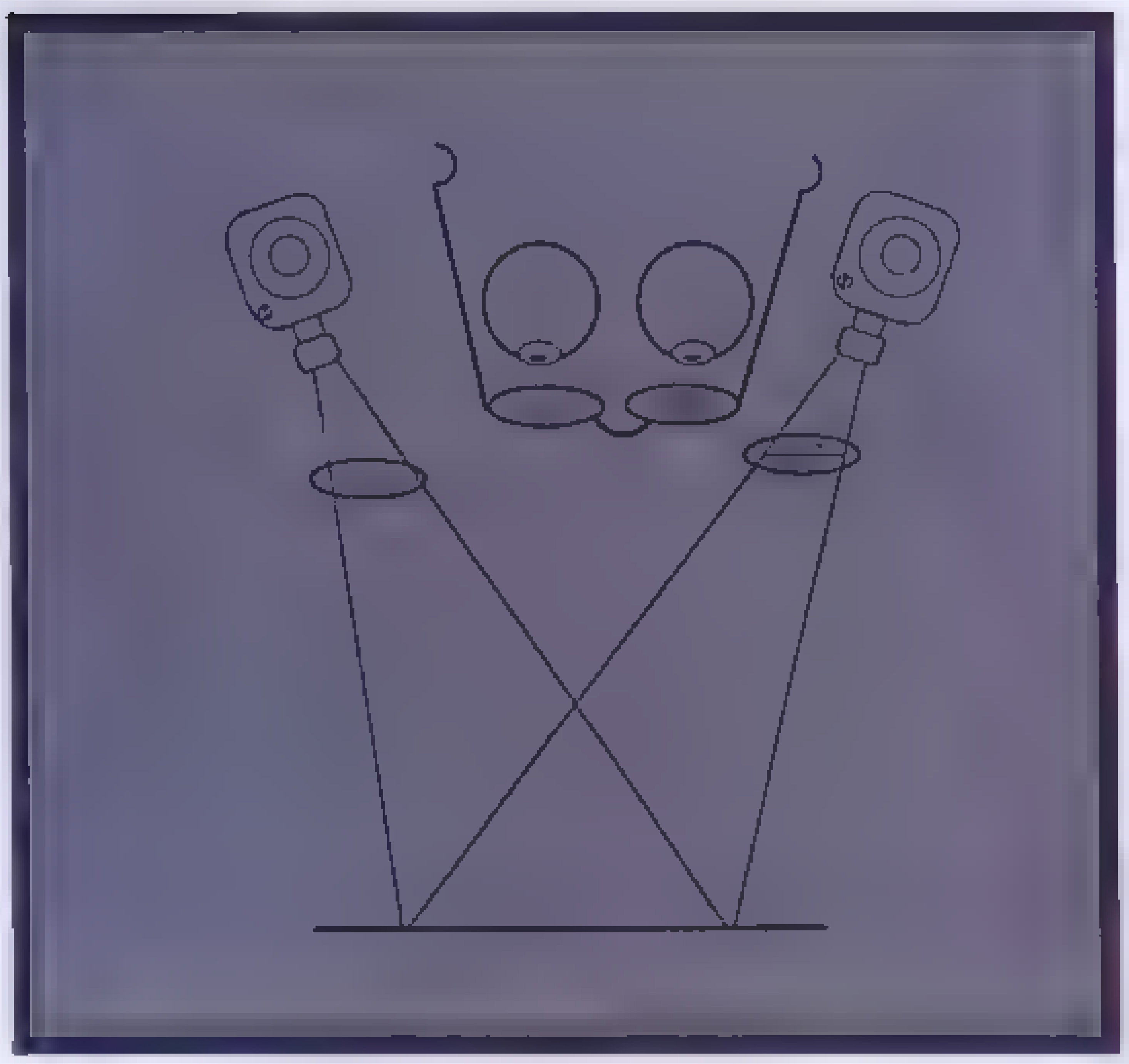
Grafpoint manufactures a comprehensive line of powerful Tektronix terminals for PCs, PS/2s, workstations, and Macintosh computers.

tion format the group at Ames could still use the Focus Graphics film recorder because it serves multiple workstations. Gary Gratny, Director of Market Development at Focus Graphics, explains, "Since our film recorders use input directly from the RGB output of the graphics controller, each is compatible with multiple workstations. In fact, ours are the only film recorders available that support multiple workstations. One of our goals is to support scientific and engineering environments, most of which have a diverse computer mix."

The Focus Graphics film recorder generates photorealistic images in seconds for a variety of film formats including slides, overheads, and animation. The newest Focus product, the ImageCorder PLUS, has an autosync feature that automatically detects video scan rate, thereby increasing its universality and ease of use in recording computer-generated images.

Once the graphics specialists at Ames record the stereopair animations on film, the films can be projected. Two projectors are used, one for the left-eye view and the other for the right-eye view (Figure 5). One film is projected through a horizontal filter; the other is projected through a vertical filter. Viewers then use glasses with transmission filters to view the film. The left lens is filtered horizontally to allow only the left-eye view to pass. The right lens is filtered vertically to allow only the right eye-view to pass. The result is a stereoscopic animation of the CFD simulated flow.



CFD stereo visualization technique using left- and right-eye view animations and special stereo glasses.

CFD Applications

Visualization of CFD data is used for research, education, and design. At NASA Ames CFD studies have been used to solve several well publicized problems that would otherwise have been difficult or impossible to overcome without computer simulations. For example, CFD was used to develop an emergency abort mode during space shuttle ascent. It has been used to examine other aspects of space shuttle ascent, including separation of the orbiter from the launch vehicle. CFD is also being applied to early development of the national aerospace plane (NASP), the aircraft that will land and take off like an airplane but will exit the atmosphere for extremely rapid global transportation.

One of the goals of CFD is to improve design and reduce costs associated with testing components under stresses, such as pressure or velocity. Already computational results have been used to enhance performance and efficiency of aerospace components. Prior to CFD studies, testing was always accomplished using physical models, such as wind tunnels or actual flights, making this step a very expensive part of the engineering process.

Once the CFD computer model is tested the simulation can be made available to industry users for further research, design, and development. NASA Ames supplies hundreds of computer programs per year to industry and research. According to Dr. Paul Kutler, Fluid Dynamics Division Chief at Ames, "One of the directions I see for computational fluid dynamics is in the area we call multi-disciplinary physics. In that area we combine not only the fluid equations but the equations governing electromagnetics or propulsion or controls into one software simulation tool." Kutler and other CFD specialists see the value of this tool applied to problems in many disciplines. They predict computational fluid dynamics will be an important and necessary methodology to keep America competitive in the global, high-technology market.

Kim Snuggerud is a freelance writer in Minneapolis, Minnesota.

For information about Focus Graphics image recorders contact Gary Gratny, Director of Market Development, Focus Graphics, Inc., 1191 Chess Drive, Foster City, California, 94404 (415) 377-0596.

For information regarding CFD at SGI contact Philip Raymond, Manager, Computational Fluid Dynamics Group, Silicon Graphics, 2011 N. Shoreline Boulevard, Mountain View, California 94039 (415) 335-1623.

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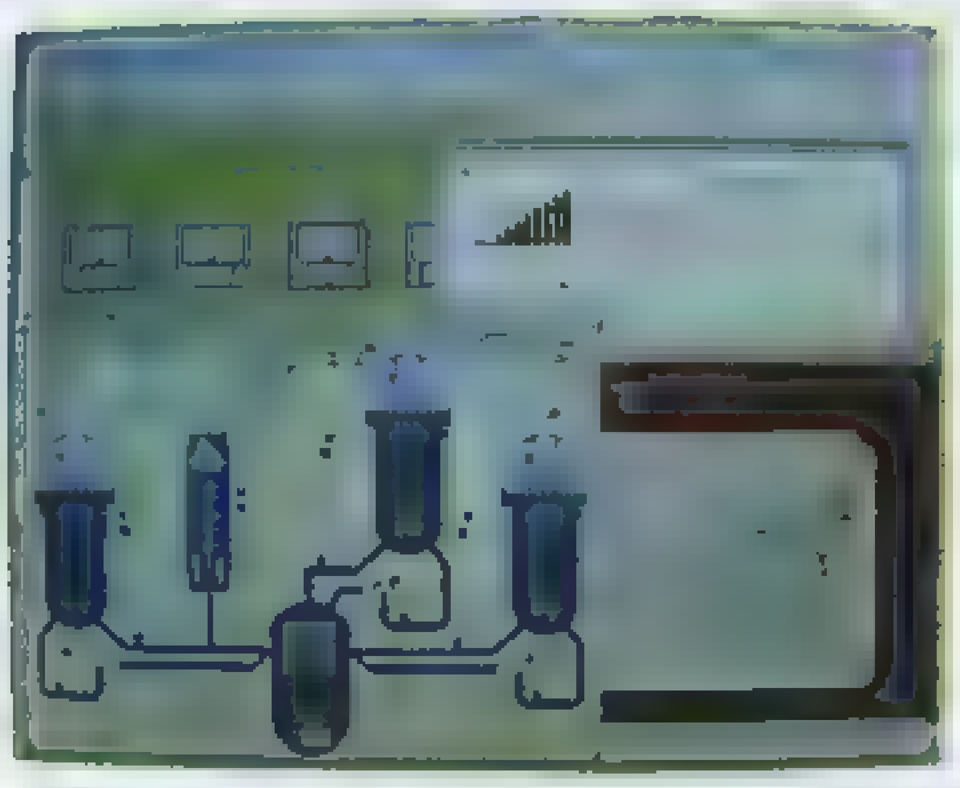

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Draw new graphical objects • Connect easily to data sources
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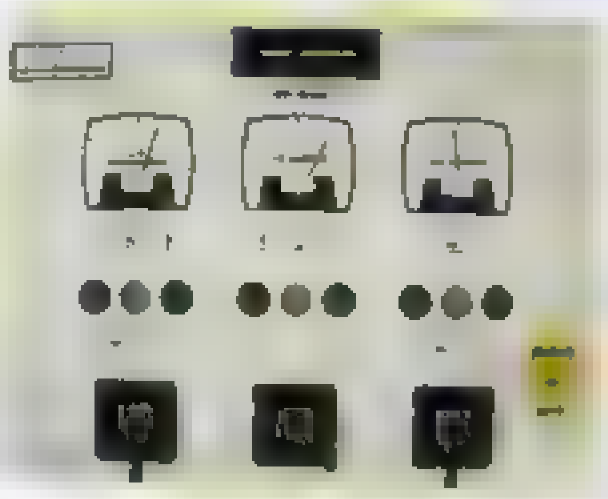
Standard widgets are not enough:

With the rise of graphics workstations has come a demand for tools that speed the development of graphics screens for applications. A bewildering array of tools has appeared to aid developers with X Windows and the primary GUI styles: MOTIF, Open Look and DECwindows. Many of these tools are WYSIWYG editors limited to the creation of standard widgets such as menus, scroll boxes, sliders and buttons. Standard widgets, however, are not enough for application visualization. Inevitably, the need arises for custom screen objects (graphs, maps, icons and other pictures) which are beyond such tools, and which are too time-consuming to create with Xlib. Developers also need a way to visualize changing data in real time.

A complete graphics tool must provide:

A Powerful Drawing Tool—The ability to create custom screen objects. Not limited to canned graph types, this flexible tool with many CAD features and an interface like familiar PC drawing tools allows you to draw whatever you need, attach dynamic behaviors and test those behaviors—all within the drawing tool.



Dynamics—The ability of screen objects to instantly reflect changes in data values, receive user input or execute callback functions. Over forty attributes such as color or text changes, visibility on/off, percent fill, line width, rotation, movement, scaling, font style or size, zooms and window creation can be triggered by changes in data values or user input.

Complete Xt Widget Integration—SL-GMS graphics can fully incorporate Xt widgets. Screen objects created with SL-GMS fully interact with MOTIF, Open Look, DECwindows or other toolkit widgets, whether in the same or different windows.

GISMOs™—Graphical Interactive Screen Management Objects are called GISMOs to distinguish them from Xt widgets. Fully interactive with Xt widgets, GISMOs can become "superwidgets", capable of complex and compound behavior beyond Xt widgets. GISMOs can take any appearance you wish and trigger any user-defined function or external program. Created with the drawing tool, GISMOs provide developers with tremendous design flexibility.

HyperCard-like Screen Management—After screens have been created, the user must be able to button from any screen to any other screen in the application. With the Screen Management System (SMS) included in SL-GMS, the developer can give the user this ability without writing a line of code. SMS is HyperCard-like but with full dynamics: SMS can bring up new screens with data sources attached and dynamics up and running.

Data Source Management—The ability to connect screen objects to data sources such as files, databases, expert systems and real-time feeds. With the Data Source Manager of SL-GMS, these connections are easily made.

Runtime Editors and Configurators—The ability of the enduser to customize or reconfigure screens to match the current environment.

Cross-Platform Portability—The ability to develop screens on any major workstation and run them on any other through simple ASCII file transfer. SL-GMS also supports PixWin, Iris GL, GKS and other non-X graphics environments. Versions such as Iris GL take advantage of special accelerator hardware and double buffering capability.

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Origami: Software for Sheet Metal Design

Origami, from Sorba Products (Holland) is a powerful CAD/CAM system designed specifically for sheet metal design and manufacturing. Companies using Origami can shorten their sheet metal design and manufacturing process by a factor of 1.5 and can make prototypes for less than 10 percent of current costs.

Origami can be used to generate NC information for any part designed, including efficient nesting of the flat pattern. Origami is available worldwide, and a U.S. office has opened recently.

For more information, contact: Sorba Products, Winterswijk, Holland (31)5340-20245, or Origami Technology Corporation, Milwaukee, Wisconsin (414) 332-5759.

3D MODELER™ from Stratysys

3D MODELER constructs plastic objects from three-dimensional wireframe, surface, or solid CAD models. 3D MODELER, driven by Strataslice™ software, accepts 3D data from CAD systems that support the IGES format, or optional .STL files. The system, based on NURBS, displays real-time object slicing on a fast 16 mips UNIX plat-

form. 3D MODELER connects to a standard RS-232 serial port and is driven by standard numerical control code. The system will be exhibited at the AUTOFACT show in Detroit.

For more information, contact: Lisa Crump, Stratasys, Inc., Minneapolis, Minnesota, (612) 941-5607.

New Storage Devices for the Personal IRIS

New storage devices and file systems have been added to the Personal IRIS (PI) product line. These storage additions allow for greater storage capacity and quicker access to stored information and can be purchased as either system or option disks. The new products include: IRIS File™, 1.2 Gigabyte disk drive, Exabyte Tape Drive, and a faster version of the 760 Mb disk drive

The IRIS File is a new user configurable shell used to hold storage devices for PIs. Previously, this cabinet was field service configured to a maximum of 1.1 Gb. Now it can be installed by the user and will hold up to five disks (three full height and two half height) with a maximum storage capacity of 7.2 Gb.

For more information, contact: Betsy Wahlquist, Silicon Graphics, (415) 962-3529.

SGI's Single Frame Video Input/Output Solution

VideoFramer™ is SGI's first single frame video input and output solution for the entire IRIS 4D™ workstation family. VideoFramer™ makes it possible to isolate or "grab" a single image from a live video source, process it using SGI's imaging and compositing features, and output the final image to video with individual frame accuracy.

VideoFramer's features include broadcast quality encoding and decoding, software controlled video setup, and remote video device control. All of the product's features can be performed while video signals are transmitted, thus freeing the workstation for other tasks. VideoFramer supports multiple formats and standards including built-in D1, D2, RGB, Betacam, NTSC, PAL, and S-Video formats. For more information, contact: Jill Grossman, Silicon Graphics, (415) 335-1516.

Alias Studio and PowerAnimator Debut at SIGGRAPH

Alias, producers of 3-D computer graphic software, debuted two new products at SIGGRAPH '90. The new Alias Studio is an interactive modeling system based on non-uniform rational b-splines (NURBS). Studio's unique surface evaluation tools called Curvature Evaluation Image (CEI) and Highlight Evaluation Image (HEI) offer immediate, precise, interactive visual evaluation.

Alias PowerAnimator is a new fully parameter-based animation system with complete digital and analog integration. New timeline animation lets animators time warp the duration of any animated sequence. Copying and instancing animated objects and animated parameters are interactive procedures.

For more information, contact: Alias Research Inc., 110 Richmond St. East, Toronto, Ontario, Canada M5C 1P1, (416) 362-9181.

TDI Announces V2.3 and New Modeler

Thompson Digital Image introduced two new major products at SIGGRAPH '90. The products are Explore V2.3, the latest version of TDI's 3-D animation software, and Explore Designer which features TDI's NURBS-based modeler.

Explore V2.3 gives animators six different ways of producing animation, including three types of keyframing and inverse kinematics for character animation.

Explore Designer is TDI's new 3-D system for computer-aided industrial design. Explore Designer gives designers great flexibility for creating complex curves and surfaces.

For more information, contact: TDI America, 1270 Avenue of the Americas, Suite 508, New York, New York 10020, (212) 247-1950.

Sigma Design Announces Version 5.7 of ARRIS Software

Sigma Design announces version 5.7 of its ARRIS AEC application software. ARRIS is a set of 12 integrated modules that provide solutions for architecture and facilities management. The new version

offers many new features and enhancements in the areas of design automation, editing, and 3-D rendering.

The following are some of the key features included in version 5.7. The new UNDO/REDO function permits continuous reversals of any ARRIS design function to accommodate multiple revisions. The SMART Columns feature automates the process of placing walls between structural columns, providing greater flexibility in the drafting of floor plans. Door/Window Generator is a new application module for creating and editing customized doors and windows in a 3-D format. Multiple "lookpaths" are now available for viewing models from different perspectives. Sigma Design engineers have also enhanced the lighting and shadowing capabilities for improved presentation graphics.

For more information, contact: Peter Kobs, Sigma Designs, Inc., Reservoir Place, 1601 Trapelo Road, Waltham, Massachusetts 02154, (617) 890-4904 or (fax) (617) 890-4914.

Environmental Concern at SGI

A new program called Scientific Analysis and Visualization of the Environment (SAVE) is in the works at Silicon Graphics. This program was inspired by SGI employees' concern about the environment and interest in finding innovative ways to put SGI's technology to use for the environment.

A laboratory will be established at Silicon Graphics equipped with graphics workstations, servers, video equipment, and a full-time staff. A goal of the lab is to help scientists and the public understand environmental issues and their impact.

With Silicon Graphics project supercomputers, it was solved in less than a year.

Fermilab operates the world's highest energy proton accelerator, where particle collision data is recorded and reconstructed. The information gained through these experiments is helping scientists determine the nature of matter.

The time and computing power required to perform these highly complex reconstructions is staggering. Because Fermilab had neither 500 years, nor the budget for 500 VAXes, they enlisted the help of four Silicon Graphics project supercomputers. And, they finished the data analysis within a year.

Parallel RISC, unparalleled performance.

Many companies, like Fermilab, that have compute-intensive tasks are discovering the advantages of Silicon Graphics project supercomputers. In fact, after just one year, Silicon Graphics has become the fourth largest supercomputing vendor, and the fastest growing, by far.

Silicon Graphics project supercomputers provide extraordinary compute power without the high cost of owning a minisupercomputer or a room full of VAXes. And they're far more cost-effective than a time-shared Cray®.

These systems can be configured with up to eight high performance RISC CPUs, in a state-of-the-art parallel architecture. They provide more than 200 VAX MIPS* and over 30 DP MFLOPS** of sustained performance, making them ideal for compute and I/O intensive scientific and engineering tasks.

Silicon Graphics project supercomputers are easily integrated into computing environments through the use of standards like UNIX®, TCP/IP, NFS™, X.11, DECnet™, VMS extensions to FORTRAN, SNA, Ultranet, FDDI, and ACCELR8™ VAX® migration tools.

A few of the organizations that are using Silicon Graphics project supercomputers today:

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E-Systems, Inc.
Electronic Data Systems Corp.
Fermi National Accelerator Lab
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IBM Corp.
Lucasfilm Ltd.
McDonnell Douglas Corp.
Minnesota Supercomputer Institute
NASA
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Rockwell International
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Second International Symposium on Electronic Art

This year's conference will be held November 12-17, 1990 in Groningen, Holland. The Symposium will be the heart of a week of electronic art events. During this week, a number of artistic applications will be brought together. Featured will be a scientific symposium, workshops on computer art and music, concerts, a film and video show, and an exhibition.

For more information, contact: SISEA, Westerhavenstraat 13, 9718 AJ Groningen, The Netherlands, (phone) 31-50-138160, (fax) 31-50-138242 or e-mail SCAN@HGRRUG5 (Bitnet)

NICOGRAPH '90

This is *the* major computer graphics convention in Japan. NICOGRAPH '90 will be held November 5-9, 1990 at several locations in Tokyo, Japan. The event includes seminars, papers, a film show, and an exhibition. The conference is sponsored by Nippon Computer Graphics Association and Nihon Keizai Shimbun, Inc.

For more information, contact: NICOGRAPH '90 Secretariat, Ogawa Bldc., 1-2-2 Uchikanda, Chiyoda-ku, Tokyo 101, Japan, (phone) +81-(0) 3-233-3475, (fax) +81-(0) 3-233-3450.

1990 ACM Conference on Critical Issues

With the theme of "Responsible Leadership in Computing", the conference will convene November 6-7, 1990 in Arlington, VA. The conference will address today's critical issues and develop an agenda for action toward solutions. Conference content will lead attendees from a

San Francisco State University, *Video Wind Chimes* by Sheldon Brown

consideration of the technology to its impact on users and society. Attendance is limited to 300.

For more information, contact: ACM. 11 West 42nd St., New York, NY 10036, (212) 869-7440 or armenti@acmvm.bitnet.

ART FUTURA '91

The second annual ART FUTURA is set in Barcelona, Spain, January 15-20, 1991. This year's focus will be on "Super Media", a look at the powerful world of media today. ART FUTURA will explore the relationships of television to art and science, graphic design to music videos, and how the computer is changing our electronic environment into a new "Super Media". Expected panelists include: Mark Pellington, Jim Blashfield, Brad Degraf, Yoichiro Kawaguchi and Brenda Laurel. There will also be a special performance by Survival Research Laboratories.

For more information, contact: ART FUTURA '91, Barcelona, Spain, (fax) 343-3152202.

Call for Visualization and Computer Animation Papers

The Journal of Visualization and Computer Animation, a quarterly, soon to publish its premiere issue, will carry research papers on technological developments as well as articles on new application areas for animated films. Critiques of films and book reviews are encouraged. Papers on all fields of scientific visualization are also welcomed. The journal will be launched in 1990 as a quarterly.

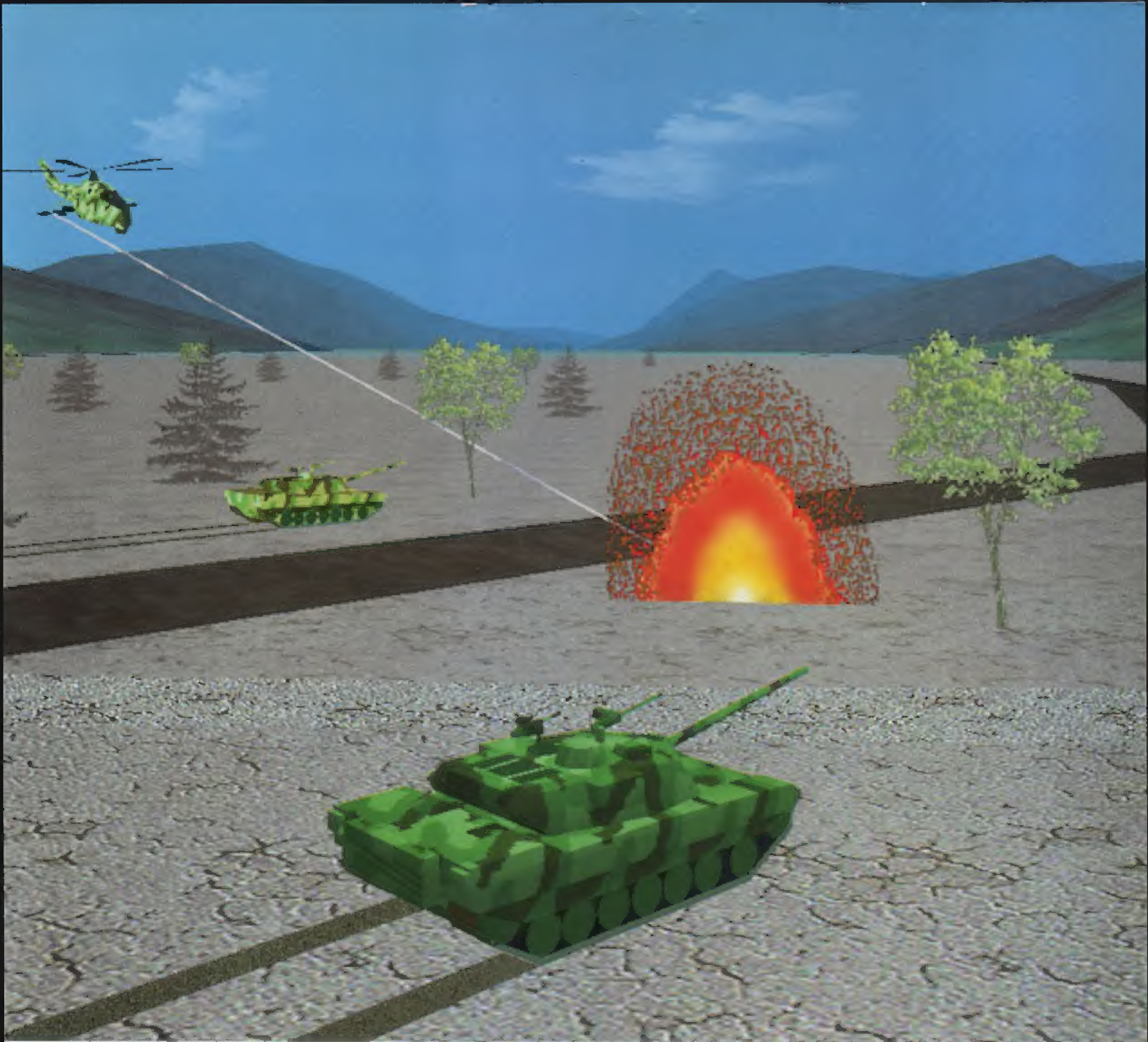
For more information, contact: Editor in Chief, Nadia Magnenat Thalman, Centre Universitaire D'Informatique, University of Geneva, 12 rue du Lac, CH-1207, Geneva, Switzerland, (phone) 4122-787-6580, (fax) 4122-735-3905 or thalmann@uni2a.unige.ch. In the U.S., you may also contact Associate Editor in Chief, E. Catmull at pixar!ec@berkeley.edu.

San Diego to Host Volume Visualization Workshop

As a follow-on to the Chapel Hill workshop, the second Volume Visualization Workshop, held December 10-11, 1990, will combine papers and demonstrations of new techniques for visualizing data defined in volumes (three dimensional arrays of datapoints). The deadline for submissions of proposals for panels and poster sessions is October 15, 1990. Instructions can be obtained from: Nick England, Sun Microsystems Inc., P.O. Box 13447, Research Triangle Park, NC 27709-3447, 919/469-8300 or nengland@sun.com.

For conference registration, contact: San Diego Workshop on Volume Visualization, San Diego Supercomputing Center, P.O. Box 85608, San Diego, CA 92138-5608, (619) 534-5000 or vvworkshop@sds.sdsc.edu.

Please send submissions for Community Forum to IRIS Universe, *Mail Stop 415, Silicon Graphics, Inc. 2011 N. Shoreline Blvd. Mountain View, California 94043.*



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4D SERIES COURSES	LOCATION* WEC	EEC	SEC
Graphics Programming 4.5 days	Nov 5, 1990 Dec 3, 1990 Jan 7, 1991 Feb 11, 1991	Dec 17, 1990 Jan 28, 1991	Jan 21, 1991 Feb 25, 1991
PowerVision Graphics Programming 2.0 days	Jan 21, 1991 Jan 22, 1991	not available	not available
Advanced Graphics 3.5/3.0 days	Nov 12, 1990 Dec 10, 1990 Feb 19, 1991	Feb 4, 1991	
Advanced Graphics & PowerVision 4.5 days	Jan 14, 1991	not available	not available
Parallel Programming 4.5 days	Feb 4, 1991	not available	not available
Mastering IRIX 4.5 days	Dec 3, 1990 Jan 28, 1991 Feb 25, 1991	Nov 26, 1990 Jan 14, 1991	Mar 11, 1991
System Administration 4.5 days	Nov 5, 1990 Dec 10, 1990 Feb 4, 1991	Nov 5, 1990 Jan 21, 1991	Jan 28, 1991
Network Administration 4.5 days	Dec 17, 1990 Feb 11, 1991	Mar 25, 1991	not available
System Maintenance Professional Series 10.0 days	Feb 4, 1991	Dec 3, 1990 Apr 29, 1991	not available
System Maintenance Power Series 4.0/10.0 days	Nov 5, 1990	not available	not available

KEY: WEC—Western Education Center, Mountain View, CA.
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*The SGI Education Center reserves the right to cancel classes due to insufficient enrollment.

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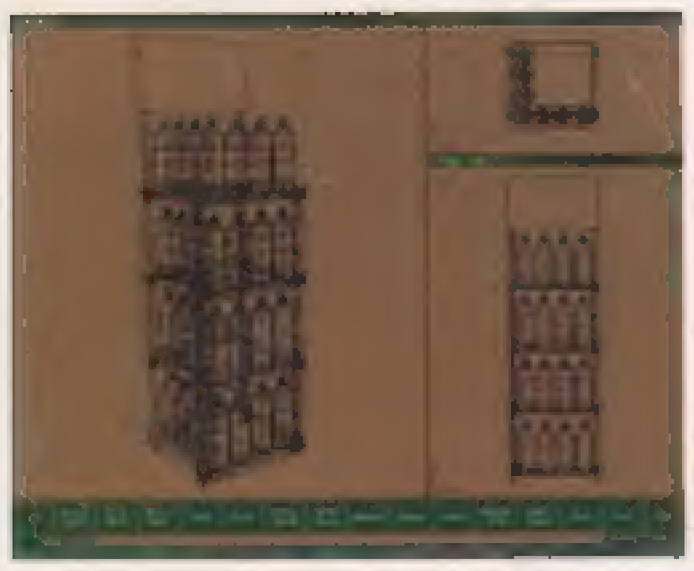

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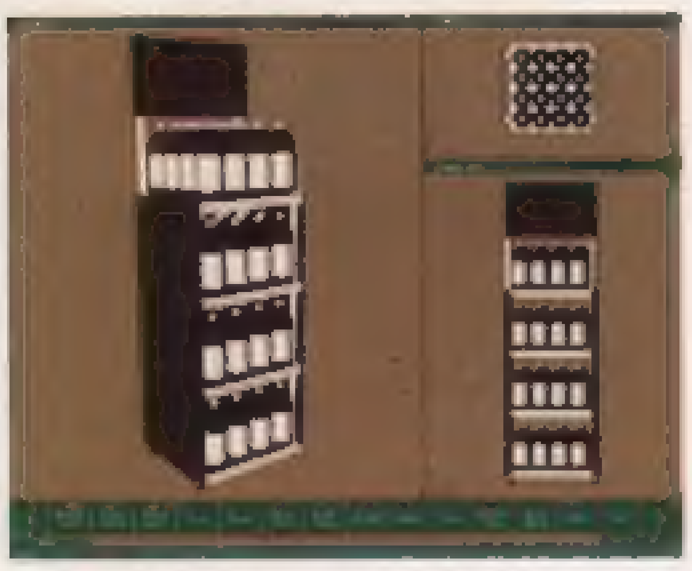

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